Attempted Takeoff From Wrong Runway
Comair Flight 5191
Bombardier CL-600-2B19, N431CA
Lexington, Kentucky
August 27, 2006



ACCIDENT REPORT

NTSB/AAR-07/05
PB2007-910406

National Transportation Safety Board

this page intentionally left blank

NTSB/AAR-07/05
PB2007-910406
Notation 7838E
Adopted July 26, 2007

Aircraft Accident Report

Attempted Takeoff From Wrong Runway
Comair Flight 5191
Bombardier CL-600-2B19, N431CA
Lexington, Kentucky
August 27, 2006



National Transportation Safety Board

490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2007. ***Attempted Takeoff From Wrong Runway, Comair Flight 5191, Bombardier CL-600-2B19, N431CA, Lexington, Kentucky, August 27, 2006.*** **Aircraft Accident Report NTSB/AAR-07/05. Washington, DC.**

Abstract: This report explains the accident involving a Bombardier CL-600-2B19, N431CA, operated by Comair, Inc., which crashed during takeoff from Blue Grass Airport, Lexington, Kentucky. The safety issues discussed in this report focus on the need for (1) improved flight deck procedures, (2) the implementation of cockpit moving map displays or cockpit runway alerting systems, (3) improved airport surface marking standards, and (4) air traffic control policy changes in the areas of taxi and takeoff clearances and task prioritization. Safety recommendations concerning these issues are addressed to the Federal Aviation Administration.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

Recent publications are available in their entirety on the Web at <http://www.ntsb.gov>. Other information about available publications also may be obtained from the Web site or by contacting:

National Transportation Safety Board
Records Management Division, CIO-40
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594
(800) 877-6799 or (202) 314-6551

Safety Board publications may be purchased, by individual copy or by subscription, from the National Technical Information Service. To purchase this publication, order report number PB2007-910406 from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
(800) 553-6847 or (703) 605-6000

The Independent Safety Board Act, as codified at 49 U.S.C. Section 1154(b), precludes the admission into evidence or use of Board reports related to an incident or accident in a civil action for damages resulting from a matter mentioned in the report.

CONTENTS

Abbreviations and Acronyms vii

Executive Summary x

1. Factual Information 1
1.1 History of Flight 1
1.2 Injuries to Persons 7
1.3 Damage to Airplane 7
1.4 Other Damage 7
1.5 Personnel Information 8
1.5.1 The Captain 8
1.5.2 The First Officer 11
1.6 Airplane Information 14
1.7 Meteorological Information 15
1.8 Aids to Navigation 15
1.9 Communications 15
1.10 Airport Information 15
1.10.1 Airport Charts 18
1.10.2 Air Traffic Control 20
1.10.2.1 Lexington Air Traffic Control Scheduling 23
1.10.2.2 Amended Takeoff Clearance Procedure 24
1.10.3 Taxi Demonstrations 24
1.10.3.1 Operations/Human Performance Observations 25
1.10.3.2 Air Traffic Control Tower Observations 27
1.10.4 Postaccident Events 28
1.11 Flight Recorders 29
1.11.1 Cockpit Voice Recorder 29
1.11.2 Flight Data Recorder 29
1.12 Wreckage and Impact Information 30
1.12.1 Wreckage Site 30
1.12.2 Airplane Wreckage 31
1.13 Medical and Pathological Information 32
1.14 Fire 33
1.15 Survival Aspects 34
1.15.1 Emergency Response 34
1.16 Tests and Research 35
1.16.1 Aircraft Performance Study 35
1.16.2 Takeoff Distance and Accelerate-Stop Calculations 35
1.17 Organizational and Management Information 36
1.17.1 Flight Manuals 36
1.17.1.1 Taxi Procedures and Briefing 36
1.17.1.2 Checklist Usage 37
1.17.1.3 Sterile Cockpit Procedures 38
1.17.1.4 Heading Bugs 38
1.17.1.5 Normal Takeoff 38
1.17.1.6 Use of Alcohol 38

1.17.1.7 Flight Crew Rest Periods 39
1.17.1.8 Crew Resource Management 39
1.17.2 Crew Resource Management Training 40
1.17.3 Safety Program Personnel Initiatives 40
1.17.4 Federal Aviation Administration Oversight 42
1.18 Additional Information 43
1.18.1 Witness Information 43
1.18.2 Related Federal Aviation Administration Guidance 43
1.18.2.1 Advisory Circular 120-74A 43
1.18.2.2 Safety Alert for Operators 06013 44
1.18.2.3 Certalert 07-01 44
1.18.2.4 Takeoff Clearance Notice 44
1.18.3 Previous Related Safety Recommendations 45
1.18.3.1 Flight Crew Operations 45
1.18.3.2 Air Traffic Control 47
1.18.4 Related Accident and Incidents 50
1.18.5 Aviation Safety Reporting System Reports 53
1.18.6 Local Notices to Airmen Information 53
1.18.7 Enhanced Taxiway Centerline Markings and Surface Painted Holding Position Signs 54
1.18.8 Department of Transportation Inspector General Report 55

2. Analysis 57
2.1 General 57
2.2 Taxi and Attempted Takeoff Sequence 57
2.2.1 Wrong Runway Departure 57
2.2.1.1 Before Taxi Activities 57
2.2.1.2 Taxi to Runway 59
2.2.1.3 Takeoff Roll 60
2.2.1.4 Runway Incursions 61
2.2.2 Pilot Human Factors 61
2.2.2.1 Available Cues and Aids for Wayfinding 62
2.2.2.2 Preflight Activities and Actions During the Taxi 63
2.2.2.3 Cues to Indicate a Takeoff From Runway 22 65
2.2.2.4 Fatigue 69
2.2.2.5 Cockpit Discipline 72
2.2.2.6 Summary of Pilot Human Factors 73
2.2.3 Air Traffic Controller Human Factors 77
2.2.3.1 Window of Opportunity During Which the Airplane Was Stopped Short of the Wrong Runway 79
2.2.3.2 Critical Window During Which an Administrative Task Was Performed 81
2.2.3.3 Fatigue 83
2.2.3.4 Summary of Air Traffic Controller Human Factors 85
2.3 Survival Factors 86
2.3.1 Impact Sequence and Injury Information 86
2.3.2 Emergency Response 88
2.3.3 Summary of Survival Factors 90
2.4 Efforts to Mitigate Airport Surface Operation Errors 90
2.4.1 Flight Deck Procedures 91
2.4.2 Technological Initiatives 93
2.4.3 Airport Surface Marking Standards 95

2.4.4 Taxi and Takeoff Clearances 96
2.4.5 Controller Monitoring Responsibility 97
2.5 Air Traffic Control Staffing 98
2.6 Other Related Issues 99
2.6.1 Airport Charts 99
2.6.2 Automatic Terminal Information Service Broadcasts 100
2.6.3 Local Notice to Airmen 101
2.6.4 Presence of Extended Taxiway Centerline 101

3. Conclusions 103
3.1 Findings 103
3.2 Probable Cause 105

4. Recommendations 106
4.1 New Recommendations 106
4.2 Previously Issued Recommendations Reiterated in This Report 107
4.3 Previously Issued Recommendations Resulting From This Accident Investigation 107
4.4 Previously Issued Recommendations Classified in This Report 108

Board Member Statements 110

5. Appendixes 120

A: Investigation and Hearing 120

B: Cockpit Voice Recorder 121

C: Blue Grass Airport Charts 158

FIGURES

1. Groundpath Before Flight 5191 Aligned With Runway 26 5
1a. Groundpath as Flight 5191 Aligned With Runway 26 6
2. Blue Grass Airport 16
3. Taxiways Leading to Runways 4/22 and 8/26 18
4. Injury Information According to Seat Assignment 33
5. Enhanced Taxiway Centerline Markings and Surface Painted Holding Position Signs 55
6. Multifunction Display 67
6a. Primary Flight Display 68
7. Air Traffic Control Event Timeline 78
8. Approximate Tree Strike Areas and Injury Informatio 87

Abbreviations and Acronyms

AC	advisory circular
ACOB	air carrier operations bulletin
AFSS	automated flight service station
agl	above ground level
APU	auxiliary power unit
ARFF	airport rescue and firefighting
ARTCC	air route traffic control center
ASAP	aviation safety action program
ASOS	automated surface observing system
ASR-7	airport surveillance radar-7
ASRS	aviation safety reporting system
ATC	air traffic control
ATCT	air traffic control tower
ATIS	automatic terminal information service
ATL	Hartsfield-Jackson Atlanta International Airport
ATOS	air transportation oversight system
BDL	Bradley International Airport
BNA	Nashville International Airport
C	Celsius
CAMI	Civil Aeromedical Institute
CFR	*Code of Federal Regulations*
cg	center of gravity
CRJ	Canadair regional jet
CRM	crew resource management
CVG	Cincinnati/Northern Kentucky International Airport

CVR	cockpit voice recorder
DBRITE	digital bright radar indicator tower equipment
DOT/IG	Department of Transportation/Inspector General
EFB	electronic flight bag
EFIS	electronic flight information system
EGPWS	enhanced ground proximity warning system
EICAS	engine indicating and crew alerting system
FAA	Federal Aviation Administration
FDR	flight data recorder
FLL	Fort Lauderdale/Hollywood International Airport
FMC	flight management computer
FMS	flight management system
FOQA	flight operations quality assurance
GRR	Gerald R. Ford International Airport
Hg	mercury
HOU	Houston Hobby Airport
HSI	horizontal situation indicator
ICAO	International Civil Aviation Organization
InFO	information for operators
JFK	John F. Kennedy International Airport
LEX	Blue Grass Airport
LOSA	line operations safety audit
MAC	mean aerodynamic chord
METAR	meteorological aerodrome report
MFD	multifunction display
MIA	Miami International Airport
msl	mean sea level

MSP	Minneapolis-St. Paul International Airport
NACO	National Aeronautical Charting Office
NAS	National Airspace System
NATCA	National Air Traffic Controllers Association
NFDC	National Flight Data Center
nm	nautical mile
NOTAM	notice to airmen
PFD	primary flight display
PIC	pilot-in-command
POI	principal operations inspector
RAAS	runway alert and advisory system
RDU	Raleigh-Durham International Airport
ROC	Greater Rochester International Airport
SAFO	safety alert for operators
SEA	Seattle-Tacoma International Airport
SMS	safety management system
S/N	serial number
TCAS	traffic alert and collision avoidance system
TRACON	terminal radar approach control
V_1	takeoff decision speed
VFR	visual flight rules
VMC	visual meteorological conditions
V_R	rotation speed

EXECUTIVE SUMMARY

On August 27, 2006, about 0606:35 eastern daylight time, Comair flight 5191, a Bombardier CL-600-2B19, N431CA, crashed during takeoff from Blue Grass Airport, Lexington, Kentucky. The flight crew was instructed to take off from runway 22 but instead lined up the airplane on runway 26 and began the takeoff roll. The airplane ran off the end of the runway and impacted the airport perimeter fence, trees, and terrain. The captain, flight attendant, and 47 passengers were killed, and the first officer received serious injuries. The airplane was destroyed by impact forces and postcrash fire. The flight was operating under the provisions of 14 *Code of Federal Regulations* Part 121 and was en route to Hartsfield-Jackson Atlanta International Airport, Atlanta, Georgia. Night visual meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board determines that the probable cause of this accident was the flight crewmembers' failure to use available cues and aids to identify the airplane's location on the airport surface during taxi and their failure to cross-check and verify that the airplane was on the correct runway before takeoff. Contributing to the accident were the flight crew's nonpertinent conversation during taxi, which resulted in a loss of positional awareness, and the Federal Aviation Administration's (FAA) failure to require that all runway crossings be authorized only by specific air traffic control (ATC) clearances.

The safety issues discussed in this report focus on the need for (1) improved flight deck procedures, (2) the implementation of cockpit moving map displays or cockpit runway alerting systems, (3) improved airport surface marking standards, and (4) ATC policy changes in the areas of taxi and takeoff clearances and task prioritization. Safety recommendations concerning these issues are addressed to the FAA.

1. Factual Information

1.1 History of Flight

On August 27, 2006, about 0606:35 eastern daylight time,[1] Comair flight 5191, a Bombardier CL-600-2B19,[2] N431CA, crashed during takeoff from Blue Grass Airport (LEX), Lexington, Kentucky. The flight crew was instructed to take off from runway 22 but instead lined up the airplane on runway 26 and began the takeoff roll. The airplane ran off the end of the runway and impacted the airport perimeter fence, trees, and terrain. The captain, flight attendant, and 47 passengers were killed,[3] and the first officer received serious injuries. The airplane was destroyed by impact forces and postcrash fire. The flight was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 and was en route to Hartsfield-Jackson Atlanta International Airport (ATL), Atlanta, Georgia. Night visual meteorological conditions (VMC) prevailed at the time of the accident.

According to a customer service agent working in the Comair operations area, the flight crew checked in for the flight at 0515.[4] The agent indicated that the crewmembers were casually conversing and were not yawning or rubbing their eyes.

The flight crew collected the flight release paperwork, which included weather information, safety-of-flight notices to airmen (NOTAM), the tail number of the airplane to be used for the flight, and the flight plan. The flight crew then proceeded to an area on the air carrier ramp where two Comair Canadair regional jet (CRJ) airplanes were parked. A Comair ramp agent, who was performing the security check of the accident airplane, noticed that the accident flight crew had boarded the wrong airplane and started its auxiliary power unit (APU). Another company ramp agent notified the flight crewmembers that they had boarded the wrong airplane. The flight crew then shut down the APU and proceeded to the correct airplane.

The LEX air traffic control tower (ATCT) was staffed with one controller at the time of the accident airplane's preflight activities, taxi, and attempted takeoff. The controller was responsible for all tower and radar positions.

The cockpit voice recorder (CVR) recording began about 0536:08. At that time, the flight crew was conducting standard preflight preparations. About 0548:24, the CVR

[1] All times in this report are eastern daylight time based on a 24-hour clock.

[2] The accident airplane was a Canadair regional jet (CRJ)-100 model, which is one of three models in the CL-600-2B19 series (the other two models are the CRJ-200 and CRJ-440). Bombardier acquired Canadair in December 1986.

[3] A pilot for another air carrier was deadheading (that is, traveling on a flight as a nonrevenue passenger) to the destination airport. He was seated in the cabin instead of on the jumpseat in the cockpit.

[4] The van driver who transported the flight crewmembers from the hotel where they stayed overnight to LEX stated that they did not appear tired and that he did not observe them yawning or stretching.

recorded automatic terminal information service (ATIS) information "alpha,"[5] which indicated that runway 22 was in use. About 1 minute afterward, the first officer told the controller that he had received the ATIS information.[6]

About 0549:49, the controller stated, "cleared to Atlanta Airport via Bowling Green, ERLIN TWO arrival.[7] Maintain six thousand [feet mean sea level (msl)] …. Departure's [departure control radio frequency] one two zero point seven five. Squawk [transponder code] six six four one." The first officer replied, "okay, got uh, Bowling Green uh, missed the other part. Six thousand, twenty point seven five. Six six four one." The controller then repeated, "it's ERLIN TWO. Echo Romeo Lima India November Two arrival," and the first officer acknowledged the arrival information.

About 0552:04, the captain began a discussion with the first officer about which of them should be the flying pilot to ATL. The captain offered the flight to the first officer, and the first officer accepted. About 0556:14, the captain stated, "Comair standard," which is part of the taxi briefing,[8] and "run the checklist at your leisure."[9]

About 0556:34, the first officer began the takeoff briefing, which is part of the before starting engines checklist. During the briefing, he stated, "he said what runway … two four," to which the captain replied, "it's two two." The first officer continued the takeoff briefing, which included three additional references to runway 22. After briefing that the runway end identifier lights were out, the first officer commented, "came in the other night it was like … lights are out all over the place." The first officer also stated, "let's take it out and … take … [taxiway] Alpha. Two two's a short taxi." The captain called the takeoff briefing complete about 0557:40.[10]

Starting about 0558:15, the first officer called for the first two items on the before starting engines checklist. When the captain pointed out that the before starting engines checklist had already been completed, the first officer questioned, "we did"?[11] Afterward,

[5] An ATIS is a continuous broadcast of recorded noncontrol information in selected terminal areas.

[6] About 0556:28, the controller advised the flight crew that ATIS information "bravo" was now current; this ATIS also stated that runway 22 was in use.

[7] ERLIN2 is a standard terminal arrival route. The flight paperwork included a different standard terminal arrival route.

[8] For information about Comair's taxi procedures and briefing, see section 1.17.1.1.

[9] The CVR showed that the captain stated, "at your leisure," several more times while giving instructions to the first officer.

[10] The first item in the before starting engines checklist is the additional crewmember briefing, which the captain called complete 1 second earlier. The takeoff briefing is the second item in the checklist.

[11] When the first officer called for the first item on the checklist, the additional crewmember briefing, the captain responded automatically and indicated that the item was complete. When the first officer called for the second item on the checklist, the takeoff briefing, the captain pointed out that the checklist had been completed.

the first officer briefed the takeoff decision speed (V_1) as 137 knots and the rotation speed (V_R) as 142 knots.[12]

Flight data recorder (FDR) data for the accident flight started about 0558:50. The FDR showed that, at some point before the start of the accident flight recording, the pilots' heading bugs[13] had been set to 227°, which corresponded to the magnetic heading for runway 22.

About 0559:14, the captain stated that the airplane was ready to push back from the gate. FDR data showed that, about 0600:08 and 0600:55, the left and right engines, respectively, were started.

About 0602:01, the first officer notified the controller that the airplane was ready to taxi. The controller then instructed the flight crew to taxi the airplane to runway 22. This instruction authorized the airplane to cross runway 26 (the intersecting runway) without stopping. The first officer responded, "taxi two two." FDR data showed that the captain began to taxi the airplane about 0602:17. About the same time, SkyWest flight 6819 departed from runway 22.

About 0602:19, the captain called for the taxi checklist. Beginning about 0603:02, the first officer made two consecutive statements, "radar terrain displays" and "taxi check's complete," that were spoken in a yawning voice. About 0603:38, American Eagle flight 882 departed from runway 22.

From about 0603:16 to about 0603:56, the flight crew engaged in conversation that was not pertinent to the operation of the flight.[14] About 0604:01, the first officer began the before takeoff checklist and indicated again that the flight would be departing from runway 22.

FDR data showed that, about 0604:33, the captain stopped the airplane at the holding position, commonly referred to as the hold short line,[15] for runway 26. Afterward, the first officer made an announcement over the public address system to welcome the passengers and completed the before takeoff checklist. About 0605:15, while the airplane was still at the hold short line for runway 26, the first officer told the controller that "Comair one twenty one" was ready to depart at his leisure; about 3 seconds later, the controller responded, "Comair one ninety one … fly runway heading. Cleared for

[12] V_1 is the maximum speed during the takeoff at which a pilot must take the first action to stop the airplane within the accelerate-stop distance (that is, the runway length required to accelerate to a specified speed and bring the airplane to a complete stop). V_R is the speed at which the rotation of an airplane is initiated to a takeoff attitude. FDR data showed that these airspeeds had been entered into the airplane's electronic flight information system.

[13] A heading bug is an indicator that is positioned around a compass rose on the primary flight and multifunction displays. It can be rotated to a specific heading for reference purposes or for commanding an autopilot to fly that heading.

[14] This conversation concerned job opportunities and was a continuation of a previous discussion that took place while the airplane was parked at the gate and the crew was conducting preflight activities.

[15] A hold short line is a painted marking on a taxiway at a runway intersection that indicates where an airplane is to stop if so instructed by air traffic control.

takeoff." Neither the first officer nor the controller stated the runway number during the request and clearance for takeoff. FDR data showed that, about 0605:24, the captain began to taxi the airplane across the runway 26 hold short line. The CVR recording showed that the captain called for the lineup checklist at the same time.

About 0605:40, the controller transferred responsibility for American Eagle flight 882 to the Indianapolis Air Route Traffic Control Center (ARTCC). FDR data showed that, about 1 second later, Comair flight 5191 began turning onto runway 26. About 0605:46, the first officer called the lineup checklist complete.

About 0605:58, the captain told the first officer, "all yours," and the first officer acknowledged, "my brakes, my controls." FDR data showed that the magnetic heading of the airplane at that time was about 266°, which corresponded to the magnetic heading for runway 26. About 0606:05, the CVR recorded a sound similar to an increase in engine rpm. Afterward, the first officer stated, "set thrust please," to which the captain responded, "thrust set." About 0606:16, the first officer stated, "[that] is weird with no lights," and the captain responded, "yeah," 2 seconds later.

About 0606:24, the captain called "one hundred knots," to which the first officer replied, "checks."[16] At 0606:31.2, the captain called, "V one, rotate," and stated, "whoa," at 0606:31.8. FDR data showed that the callout for V_1 occurred 6 knots early and that the callout for V_R occurred 11 knots early; both callouts took place when the airplane was at an airspeed of 131 knots. FDR data also showed that the control columns reached their full aft position[17] about 0606:32 and that the airplane rotated at a rate of about 10° per second.

The airplane impacted an earthen berm[18] located about 265 feet from the end of runway 26, and the CVR recorded the sound of impact at 0606:33.0. FDR airspeed and altitude data showed that the airplane became temporarily airborne after impacting the berm but climbed less than 20 feet off the ground.

The CVR recorded an unintelligible exclamation by a flight crewmember at 0606:33.3. FDR data showed that the airplane reached its maximum airspeed of 137 knots about 0606:35. The aircraft performance study for this accident showed that, at that time, the airplane impacted a tree located about 900 feet from the end of runway 26. The CVR recorded an unintelligible exclamation by the captain at 0606:35.7, and the recording ended at 0606:36.2.

Figures 1 and 1a show key events in the airplane's taxi to and attempted takeoff from runway 26.

[16] The first officer's statement indicated that the airspeed displayed on his indicator was the same as that displayed on the captain's indicator.

[17] FDR data showed that the right control column position reached 10.9° and that the left control column position reached 10.6°. According to the Bombardier CRJ maintenance manual, the control column aft travel limit is 11.1° ± 1.5°. FDR data for the accident airplane's previous 12 takeoffs showed that the nominal control column input for rotation was between 4° and 5°.

[18] The height of the berm, relative to the immediate terrain, was about 4 feet.

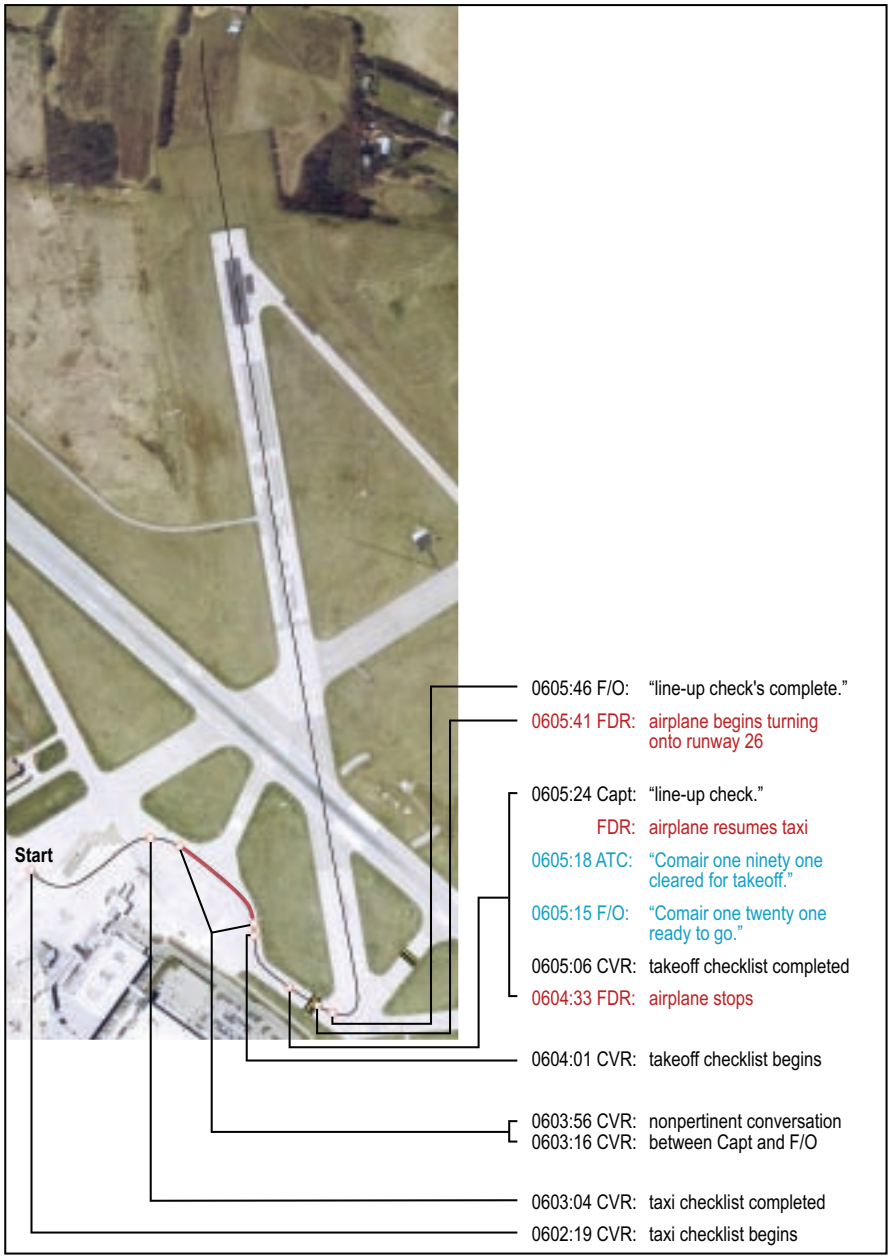


Figure 1. Groundpath Before Flight 5191 Aligned With Runway 26

Note: The runway configuration shown in this figure reflects the configuration that was in place at LEX before August 20, 2006. The runway and taxiway configurations at the time of the accident are shown in figures 2 and 3 of this report.

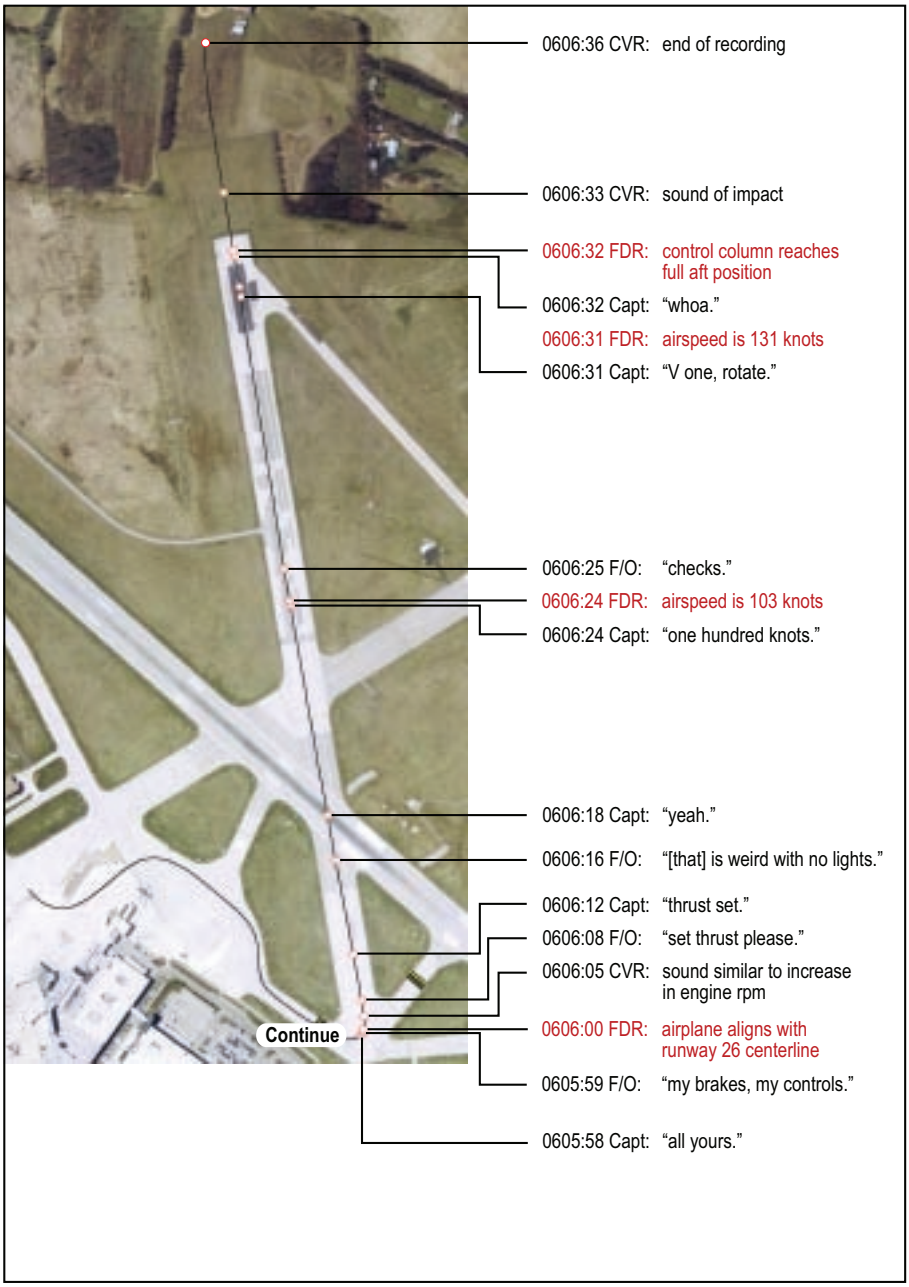


Figure 1a. Groundpath as Flight 5191 Aligned With Runway 26

Note: The runway configuration shown in this figure reflects the configuration that was in place at LEX before August 20, 2006. The runway and taxiway configurations at the time of the accident are shown in figures 2 and 3 of this report.

In a postaccident interview, the controller stated that he did not see the airplane take off.[19] The controller also stated that, after hearing a sound, he saw a fire west of the airport and activated the crash phone (the direct communication to the airport's operations center and fire station) in response. The air traffic control (ATC) transcript showed that the crash phone was activated about 0607:17 and that the airport operations center dispatcher responded to the crash phone about 0607:22. According to the ATC transcript, the controller announced an "alert three"[20] and indicated that a Comair jet taking off from runway 22 was located at the west side of the airport just off the approach end of runway 8 (which is also the departure end of runway 26). Section 1.15.1 discusses the emergency response.

1.2 Injuries to Persons

Table 1. Injury chart.

Injuries	Flight Crew	Cabin Crew	Passengers	Other	Total
Fatal	1	1	47	0	49
Serious	1	0	0	0	1
Minor	0	0	0	0	0
None	0	0	0	0	0
Total	2	1	47	0	50

Note: Title 49 CFR 830.2 defines a serious injury as any injury that (1) requires hospitalization for more than 48 hours, starting within 7 days from the date that the injury was received; (2) results in a fracture of any bone, except simple fractures of fingers, toes, or the nose; (3) causes severe hemorrhages or nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns or any burns affecting more than 5 percent of the body surface.

1.3 Damage to Airplane

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

1.4 Other Damage

A perimeter fence gate on the airport property and numerous trees beyond the airport property received damage from the airplane's impact.

[19] The controller's actions at this time are further discussed in section 1.10.2.

[20] As indicated in the airport's emergency plan and the letter of agreement between the airport board and the ATCT, an alert 3 indicates that an aircraft has been involved in an accident on or near the airport.

1.5 Personnel Information

1.5.1 The Captain

The captain, age 35, held an airline transport pilot certificate and a Federal Aviation Administration (FAA) first-class medical certificate dated August 21, 2006, with a limitation that required him to wear corrective lenses while exercising the privileges of this certificate.[21] The captain received a type rating on the CL-65 on January 14, 2004. (The CL-600-2B19 airplane is included in the CL-65 type rating.)

The captain attended the professional pilot program at Comair Aviation Academy, Sanford, Florida, from July 1997 to August 1998. After graduation, the captain was employed as a flight instructor at the academy.[22] The captain was hired by Comair in November 1999 and upgraded from first officer to captain in January 2004. At the time of the accident, he was based at Cincinnati/Northern Kentucky International Airport (CVG), Covington, Kentucky, as a reserve captain. The captain's aviation résumé before his employment with Comair indicated that he had experience flying various general aviation airplanes.

Comair employment and flight records indicated that the captain had accumulated 4,710 hours of total flying time, including 3,082 hours on the CL-65 and 1,567 hours as a CL-65 pilot-in-command (PIC). He had flown 571, 159, 56, and 8 hours in the 12 months, 90 days, 30 days, and 7 days,[23] respectively, before the accident. The captain's last PIC line check occurred on May 12, 2006; his last recurrent ground training occurred on November 16, 2005; and his last recurrent proficiency check occurred on July 31, 2006. FAA records indicated no accident or incident history or enforcement action, and a search of records at the National Driver Register found no history of driver's license revocation or suspension.

Comair records indicated that the captain had landed at or taken off from LEX six times (not including the accident flight) since September 2004. Three of the arrivals occurred during night conditions, and two of the departures (not including the accident flight) occurred during night conditions. His last flights to and from LEX before the accident trip sequence were on June 16, 2006 (during the day), and June 17, 2006 (at night), respectively.

[21] The captain's medical records showed that his distant and near vision measurements were corrected to 20/20 in each eye and combined (with no measurements listed for uncorrected vision). A medical application dated February 3, 2004, showed that the captain's uncorrected distant vision measurement was 20/100 and that his uncorrected near vision measurement was 20/20. The captain's medical records also indicated that he passed his color vision examination and that he had a normal field of vision.

[22] The captain's flight instructor certificate (airplane single- and multiengine–instruments) was issued in August 1998.

[23] According to Comair's Operations Manual, chapter 3, section 3.8.3, page 3-20, "Flight Time Limitations and Rest Requirements," dated June 10, 2005, flight time limits must not exceed 1,000 hours in any calendar year, 100 hours in any calendar month, or 30 hours in any 7 consecutive days.

The check airman who flew with the captain for his line check in May 2006 stated that he received standard scores (three out of a possible four). The first officer who flew with the captain on a six-leg trip on August 25 and 26, 2006, described him as someone who was "by the book" but easy to talk to and get along with. This first officer stated that the captain established a good atmosphere in the cockpit and demonstrated good crew resource management (CRM).[24] This first officer further stated that the captain was in a good mood during the trip and that he did not recall the captain making any specific mistakes. A first officer who flew with the captain on August 20, 2006, stated that he would have had no problem speaking up to the captain if it had been necessary. A first officer who flew with the captain in early August 2006 stated that the captain followed standard operating procedures and called for checklists at the appropriate time. All of the interviewed Comair pilots who had flown with the captain reported that he had no difficulties navigating airports. In addition, instructors and check airmen stated that they had not heard anything negative about the captain.

According to his wife, the captain was in good health and exercised regularly. She stated that he was a nonsmoker who did not drink alcohol often and did not take any medications.[25] The captain's wife also stated that his finances were stable and that he had not experienced any financial, health, or major life changes, besides the birth of their second child in May 2006, during the year that preceded the accident. She further stated that he did not take any sleep aids, had fairly normal sleep patterns, was "cheery" in the morning, and drank a cup of coffee each morning. She indicated that he wore contact lenses all of the time and that his night vision was fine. In addition, the captain's wife stated that there was nothing remarkable or unusual about his activities or schedule in the days that preceded the accident.

During the 4 days that preceded the accident, the captain's activities were as follows:

- On Wednesday, August 23, 2006, the captain was off duty. He awoke that day at 0800 and drove with his family during the afternoon from eastern Kentucky (where his relatives lived) to his home near the CVG area. After he arrived home, the captain ate dinner, performed routine activities around the house, and watched television.
- On Thursday, August 24, 2006, the captain awoke about 0630 and spent the day running errands and performing routine activities around the house.
- On Friday, August 25, 2006, the captain awoke about 0615. He drove 40 minutes to CVG and checked in for his "ready reserve"[26] assignment about 0752. The captain was notified of a 2-day, six-leg trip assignment about 1225. The first

[24] This first officer stated that a newly trained first officer was occupying the cockpit jumpseat during one of the flight legs on August 25, 2006, and that the captain briefed the newly trained first officer about the importance of adhering to the company's sterile cockpit procedures (also known as sterile cockpit discipline). Section 1.17.1.3 discusses the FAA's and the company's sterile cockpit procedures.

[25] The captain's August 21, 2006, FAA medical application indicated that he did not use any prescription or nonprescription medications.

[26] Ready reserve is standby duty at an airport while waiting for a flight assignment.

leg departed CVG about 1432 and arrived at Gerald R. Ford International Airport (GRR), Grand Rapids, Michigan, about 1548. The second leg departed GRR about 1603 and arrived at CVG about 1710. The third leg departed CVG about 1809 and arrived at Minneapolis-St. Paul International Airport (MSP), Minneapolis, Minnesota, about 2006.[27] The captain and the first officer for this trip went to a hotel in the MSP area. Telephone records showed that the captain called his home telephone number about 2149 and that the call lasted for about 4 minutes.

- On Saturday, August 26, 2006, the captain met the first officer for the second day of the trip about 0630 for a 0640 scheduled report time at MSP. The fourth leg of the trip departed MSP about 0740 and arrived at CVG about 0935, after which the captain was informed about a modification to his trip. In addition to the planned fifth and sixth legs of the trip, the captain would also be deadheading from CVG to LEX, flying three legs on August 27, and deadheading from ATL to CVG afterward.[28]

  The fifth leg of the trip departed CVG about 1039 and arrived at Nashville International Airport (BNA), Nashville, Tennessee, about 1145. The sixth leg of the trip departed BNA about 1210 and arrived at CVG about 1306. The flight from CVG to LEX departed about 1429 and arrived about 1526, and the captain was released from duty about 1546.[29]

  The captain arrived at a hotel in the LEX area.[30] Because of the length of his layover, the captain's family picked him up for dinner outside of the hotel about 1630. The captain returned to the hotel alone,[31] where, according to his wife, he spent the evening watching television. Telephone records showed that the captain called his home telephone number about 2123 and that the call lasted for about 4 minutes. The captain's wife stated that he was planning to go to sleep after the call had ended.
- On Sunday, August 27, 2006, the captain received a wakeup call about 0415. He reported for duty at LEX at 0515.[32] The captain's wife did not speak with him that day.

The accident flight was the first one that paired the captain and the first officer.

---

[27] Comair records showed that the captain's duty day was 12 hours 26 minutes.

[28] The first officer for the six-leg trip stated that the captain was disappointed about the extension of the trip but took it in stride and was not distracted during the remaining flight legs.

[29] Comair records showed that the captain's duty day was 9 hours 6 minutes.

[30] The hotel computer system indicated front desk activity associated with the captain's assigned room about 1554. The hotel's general manager stated that this activity might not correspond to the actual time that the captain checked in. Hotel key card records showed activity for the captain's room at 1458 and 1511; however, after the accident, hotel personnel tested the lock on the captain's room and determined that the actual time of key card activity was 1 hour later than indicated in the records (that is, 1558 and 1611).

[31] Hotel key card records showed activity for the captain's room at 1813 (1913 with the 1-hour correction indicated in the previous footnote). No further key card activity occurred after this time.

[32] Comair required that pilots report for duty at field locations away from the pilots' home base 45 minutes before a flight's departure. The accident flight was scheduled for departure at 0600.

1.5.2 The First Officer

The first officer, age 44, held an airline transport pilot certificate and an FAA first-class medical certificate dated July 18, 2006, with a limitation that required him to wear corrective lenses while exercising the privileges of this certificate.[33] The first officer received a type rating on the CL-65 (second-in-command privileges only) on November 3, 2005.[34]

In 1995, the first officer began the American Flyers flight school pilot training program. In March 1997, he began working for Gulfstream International Airlines; during his employment there, he was a captain on the Beech 1900 and a simulator instructor. The first officer was hired by Comair in March 2002 and was based at John F. Kennedy International Airport (JFK), Jamaica, New York.

Comair employment and flight records indicated that the first officer had accumulated 6,564 hours of total flying time, including 940 hours as PIC and 3,564 hours on the CL-65. He had flown 876, 245, 64, and 18 hours in the 12 months, 90 days, 30 days, and 7 days, respectively, before the accident. The first officer's last recurrent proficiency check occurred on April 6, 2006, and his last recurrent ground training occurred on April 4, 2006. FAA records indicated no accident or incident history or enforcement action, and a search of records at the National Driver Register found no history of driver's license revocation or suspension.

Comair records indicated that the first officer had landed at or taken off from LEX 12 times (not including the accident flight) since September 2004. Six of the arrivals occurred during night conditions, and one of the departures (not including the accident flight) occurred during night conditions. His last flights to and from LEX before the accident flight were on August 26, 2006 (at night), and May 19, 2006 (during the day), respectively.

The check airman who gave the first officer his April 2006 line-oriented evaluation in the simulator stated that the first officer met standards and that nothing stood out regarding his performance during the evaluation. The captain who flew with the first officer on August 25, 2006, stated that the first officer was involved with decision-making and had good situational awareness. This captain further stated that, during their flights together, the first officer consistently had his taxi charts out without prompting. The captain who flew with the first officer on a 3-day trip from August 20 to 22, 2006, stated that the first officer was articulate while performing the checklist and that he ensured that the captain was "with him" before going forward to the next item. The captain who flew with the first officer during a 5-day trip from August 9 to 13, 2006, described the first officer as a "thorough by-the-book pilot" who met standards and demonstrated good CRM. This captain, who was also a check airman, stated that the first officer used standard

[33] The first officer's medical records indicated that his distant vision measurement was 20/30 corrected to 20/20 in each eye and combined and that his near vision measurement was 20/20 (with no measurement listed for corrected vision in each eye and combined). The first officer's medical records also indicated that he passed his color vision examination and that he had a normal field of vision.

[34] The first officer also received a flight instructor certificate (airplane single engine) in November 1996 and a type rating on the Beech 1900 in November 2000.

phraseology when performing checklists and demonstrated situational awareness and good sterile cockpit discipline. Finally, pilots, instructors, and check airmen stated that they had not heard anything negative about the first officer, and pilots who had flown with the first officer stated that he was looking forward to upgrading to captain.[35]

National Transportation Safety Board investigators were unable to interview the first officer as part of this accident investigation. His attending physician stated that the first officer was "medically unfit" to be interviewed. The first officer's wife stated that he did not remember the accident.

According to his wife, the first officer was in good health and exercised regularly. She stated that he drank alcohol occasionally and took a prescription medication to lower cholesterol.[36] The first officer's wife also stated that he had not experienced any major life changes during the year that preceded the accident but that he was affected by Comair's pay cuts.[37] She further stated that the first officer was generally a morning person who sometimes drank a cup of coffee in the morning. A captain and friend of the first officer described him as an evening person and recalled conversations they had regarding the difficulty of going to bed on nights that preceded an early report time.[38] The first officer's wife indicated that he did not have any sleep disorders. She also indicated that he wore contact lenses for a short time and had excellent night vision.[39] In addition, the first officer's wife indicated that there was nothing remarkable or unusual about his activities or schedule in the days that preceded the accident.

The first officer was not on duty on August 23 and 24, 2006. The Safety Board attempted to determine the first officer's activities during the 72 hours that preceded the accident but was only able to determine some of the first officer's activities during the 2 preceding days,[40] which were as follows:

- On Friday, August 25, 2006, the first officer commuted from his home near Fort Lauderdale/Hollywood International Airport (FLL), Fort Lauderdale, Florida, to JFK to report at 1150 for a 3-day trip. (His flight departed from

[35] A progress report in the first officer's file showed the highest rating (superior) for all performance elements, and the captain who submitted the progress report indicated on the form that the first officer was captain material. Other pilots who had recently flown with the first officer stated that they knew he was preparing to upgrade to captain and that he would make a good captain because of his adherence to standard operating procedures, experience, maturity, and good CRM.

[36] The first officer's July 18, 2006, FAA medical application indicated that he did not use any prescription or nonprescription medications.

[37] A captain who had recently flown with the first officer stated that the company's pay cuts affected first officers more than captains because first officers are at the lower end of the pay scale. This captain also stated that the pay cut was not necessarily a concern for this first officer.

[38] According to this captain, he and the first officer discussed the difficulty of going to bed at 2100 on nights that preceded an early report time but that going to bed at 2300 resulted in less but better-quality sleep.

[39] LEX security camera video showed that the first officer was not wearing glasses when he passed through the operations area on the day of the accident. The captain who flew with the first officer from August 20 to 22, 2006, stated that he did not wear glasses during the flights.

[40] The first officer's wife did not remember his activities from August 23 to 25, 2006.

FLL about 0559 and arrived at JFK at 0832.) The first leg of the trip departed JFK about 1305 and arrived at Greater Rochester International Airport (ROC), Rochester, New York, about 1435. The next leg of the trip departed ROC about 1600 for JFK but diverted to Bradley International Airport (BDL), Windsor Locks, Connecticut, for fuel,[41] arriving about 1815. The flight departed BDL about 1839 and arrived at JFK about 1955. Because of the airplane's late arrival, Comair asked the pilots to reposition the airplane to LEX. According to the captain of this flight, the airplane pushed back from the gate about 2130 but did not take off until about 2300.

- On Saturday, August 26, 2006, the repositioning flight landed on runway 22 at LEX[42] about 0140.[43] According to the captain of this flight, the first officer checked into his hotel room about 0210.[44]

  Telephone records showed that the first officer made a call about 1443. Hotel key card records showed activity for the first officer's room about 1530.[45] A receipt from the hotel restaurant showed that the first officer purchased something to eat and two bottles of beer about 1826. Telephone records indicated that the first officer called the Comair System Operations Control Center about 1836 and 1844.[46] The records also indicated that the first officer called his wife about 2049 and that the call lasted about 13 minutes. According to his wife, the first officer stated that he had been able to sleep in that morning and was going to bed early. She stated that he sounded "good as usual."

- On Sunday, August 27, 2006, mobile phone records showed that the first officer received a 24-second call about 0103 followed immediately by a 37-second call that went to voicemail.[47] The originating telephone number was identified

[41] While en route to JFK, the flight crew received delaying vectors and holds from ATC and, as a result, decided to divert.

[42] The captain of this flight reported that the left runway edge lights were illuminated but that only one-eighth of the right runway edge lights were illuminated. (The right runway edge lights were out after the intersection of runway 22 with runway 26.) A NOTAM that was in effect at the time indicated that numerous right runway edge lights were out of service.

[43] The first officer's duty time for August 25 and 26, 2006, was 14 hours 10 minutes, including 9 hours 11 minutes of flight time. The captain of the flights stated that neither he nor the first officer took a nap when they were not flying.

[44] The hotel computer system indicated front desk activity associated with the first officer's assigned room about 0158. The hotel's general manager stated that this activity might not correspond to the actual time that the first officer checked in. Hotel key card records showed activity for the first officer's room at 2257 on August 25, 2006; however, after the accident, hotel personnel tested the lock on the first officer's room and determined that the actual time of key card activity was 2 hours later than indicated in the records (that is, 0057 on August 26). Section 2.2.2.4 further discusses the time of the key card activity for the first officer's room.

[45] The time of the key card activity, with the 2-hour correction stated in the previous footnote, was 1730.

[46] These conversations were regarding the first officer's report time for the next day. His report time was originally scheduled for 0530 but was changed to 0515.

[47] The Safety Board could not determine whether the first officer attempted to answer these calls.

as that of the first officer's brother.[48] Telephone records showed that the first officer called the Comair System Operations Control Center about 0510 and that the call lasted 2 minutes 17 seconds.[49] The first officer reported for duty at LEX at 0515.

1.6 Airplane Information

The accident airplane, a Bombardier CL-600-2B19, serial number 7472, was manufactured in January 2001 and was delivered new to Comair. At the time of the accident, the airplane had accumulated 14,536 total flight hours and 12,048 total flight cycles.[50]

The airplane was equipped with two General Electric CF34-3A1 turbofan engines. The left (No. 1) engine was delivered new to Bombardier in December 1998 and was installed on the accident airplane on August 3, 2006. The left engine had accumulated 17,265 total flight hours and 14,850 total flight cycles since new. The right (No. 2) engine was delivered new to Bombardier in September 1994 and was installed on the accident airplane in November 2005. The right engine had accumulated 27,327 total flight hours and 25,373 total flight cycles since new.

The airplane's electronic flight information system (EFIS) was manufactured by Rockwell Collins and contained six electronic flight display positions. The captain's and the first officer's stations each contained multifunction display (MFD) and primary flight display (PFD) positions; the MFDs were located inboard of the PFDs. The panel between the captain's and the first officer's stations contained the engine indicating and crew alerting system (EICAS) positions. The MFDs included a present position map mode with which range settings of 5, 10, 20, 40, 80, 160, and 320 nautical miles (nm) could be selected and autopilot heading select information and weather and terrain information (on radar overlays) could be displayed.[51] The PFDs displayed airspeed, altitude, attitude, and heading information.

The airplane was configured with two cockpit flight crew seats; one cockpit observer's seat; one retractable, aft-facing flight attendant jumpseat, which was mounted on the forward bulkhead; and 50 coach-class passenger seats.

A review of the airplane's maintenance logbooks from February 1 to August 7, 2006, showed that the maintenance records were up to date and complete with no

[48] During a postaccident interview, the first officer's brother did not remember placing the calls.

[49] This conversation was concerning the first officer's desire to deadhead to another base (at the end of his duty day) rather than the one originally assigned. The Safety Board listened to a tape of this telephone call. The first officer spoke clearly and was conversational throughout the call.

[50] A cycle is one complete takeoff and landing sequence.

[51] FDR data showed that the captain's and the first officer's MFDs were set to the present position map mode. The captain's MFD range was set to 80 nm, and the first officer's MFD range was initially set to 10 nm but was switched to 40 nm about 4 minutes before the takeoff roll. The captain's and the first officer's autopilot headings were set to 227°, and the MFD radar overlays were active.

discrepancies noted. The airplane's last maintenance check (a line check) occurred on the day of the accident.

The load manifest showed that the airplane's takeoff weight was 49,087 pounds with a forward center of gravity (cg) of 12 percent mean aerodynamic chord (MAC), which was within the airplane's maximum allowable takeoff weight for the accident flight of 50,178 pounds and its forward cg range of 9 to 12 percent MAC.

1.7 Meteorological Information

LEX has an automated surface observing system (ASOS), which is maintained by the National Weather Service. Augmentation and backup of the ASOS are provided by FAA personnel in the LEX ATCT. The ASOS records continuous information on wind speed and direction, cloud cover, temperature, precipitation, and visibility.[52] The ASOS transmits an official meteorological aerodrome report (known as a METAR) each hour. The 0554 METAR indicated the following: winds from 200° at 7 knots, visibility 8 miles, few clouds at 9,000 feet, scattered clouds at 12,000 feet, temperature 24° Celsius (C), dew point 19° C, and altimeter setting 30.00 inches of mercury (Hg). The 0654 METAR indicated the following: winds from 220° at 8 knots, visibility 8 miles, few clouds at 4,700 feet, ceiling 6,000 feet broken and 9,000 feet overcast, temperature 23° C, dew point 20° C, altimeter setting 30.02 inches of Hg, rain began at 0612 and ended at 0651, 0.01 inch of precipitation measured.[53]

Sunrise at LEX on August 27, 2006, was at 0703, which was about 1 hour after the accident occurred. At the time of the accident, the moon was below the horizon.

1.8 Aids to Navigation

No problems with any navigational aids were reported.

1.9 Communications

No communications problems were reported.

1.10 Airport Information

LEX is located about 4 miles west of the city of Lexington at an elevation of 970 feet msl. The airport has two runways, 4/22 and 8/26, as shown in figure 2.

[52] Cloud cover is expressed in feet above ground level. Visibility is expressed in statute miles.

[53] LEX security camera video from 0600 to 0607 showed no evidence of rain or restrictions to visibility at the time of the accident airplane's taxi and attempted takeoff.



Figure 2. Blue Grass Airport

Source: Lexington, Kentucky, Police Department

Runway 4/22, the air carrier runway, was 7,003 feet long and 150 feet wide. It had high intensity runway lights.[54] Runway 4/22 also had centerline lights and runway end identifier lights, but they were out of service at the time of the accident because of a construction project (as discussed in this section). Runway 4/22 conformed with the FAA airport certification requirements specified in 14 CFR 139.[55]

Runway 8/26, the general aviation runway, was used for about 2 percent of the airport's total operations. It was not subject to the requirements of 14 CFR 139.[56] Runway 8/26 was 3,501 feet long and 150 feet wide, but the paint markings limited the usable runway width to 75 feet.[57] Runway 8/26 was used only for flights conducted when daytime visual flight rules (VFR) prevailed and for aircraft that weighed less than 12,500 pounds. Although the runway was equipped with runway edge lights when the

[54] High intensity runway lights have five settings, step 1 through step 5, with step 5 being the brightest setting. At the time of the accident, the lights were on step 3.

[55] Title 14 CFR 139 established minimum standards for airports that conduct U.S. air carrier operations. These standards include runway and runway safety area dimensions, airport lighting and markings, airport signage, and emergency response capabilities. Taxiways A and C (and their associated connectors) were also required to conform with 14 CFR Part 139.

[56] Runway 8/26 was not used by scheduled passenger-carrying aircraft with more than 9 passenger seats or unscheduled passenger-carrying aircraft with at least 31 passenger seats.

[57] According to the LEX director of operations, the 150-foot runway width was narrowed to 75 feet in 2001 because of pavement deterioration on the runway edges.

width was 150 feet, these lights had been disconnected since 2001 when the runway was designated for daytime VFR use only.[58] Runway 8/26 crossed runway 4/22 about 700 feet south of the runway 4/22 threshold. A 2,000-foot distance-remaining marker and a 1,000-foot distance-remaining marker appeared on the north side of runway 8/26 after the intersection with runway 4/22.[59] The hold short line for runway 26 was about 560 feet from the hold short line for runway 22.

At the time of the accident, LEX was nearing the completion of a multiyear construction project. The project included shifting runway 4/22 325 feet to the southwest to accommodate a longer runway safety area at the approach end of runway 22, relabeling the existing taxiway connectors, demolishing taxiway A5 and taxiway A north of runway 8/26,[60] and creating a new taxiway (labeled A7) at the end of runway 22.

From August 18 to 20, 2006, LEX was closed to resurface and paint new markings on runway 4/22 and change taxiway connector signage. On August 20, the airport was reopened at 1800, a local NOTAM was issued to announce the closure of taxiway A north of runway 8/26,[61] and low-profile barricades with flashing red lights were placed on that part of the taxiway. Former taxiway A5 was redesignated as taxiway A and was used by airplanes to access runway 22 before the construction of the new taxiway A7, which was planned to be completed about 30 to 45 days after the completion date of the repaving project (August 20). Figure 3 shows the locations of the existing (A), planned (A7), and former (A5 and A north of runway 8/26) taxiways.

On August 27, 2006, as a result of the accident, a NOTAM was issued to announce the closure of runway 8/26, and lighted "X" markings were placed at the end of each runway 2 days later. Runway 8/26 remained closed until November 1, 2006, when new taxiway A7 was opened.

[58] The disconnected runway edge lights could only be turned on by maintenance personnel.

[59] These distance-remaining markers were unlighted. The marker lights were on the same circuit as the runway edge lights, which had been disconnected when the runway was designated for daytime VFR use only.

[60] According to the program manager of the LEX construction project at the FAA's Memphis, Tennessee, Airports District Office, it would not have been possible to continue to use taxiway A north of runway 8/26 to taxi airplanes to the new runway 22 threshold because that would have violated terminal instrument procedures criteria.

[61] This information was not included in the ATIS information recordings on the day of the accident but was included in a sampling of ATIS broadcasts recorded each day between 0530 and 0630 from August 20 to 26, 2006.



Figure 3. Taxiways Leading to Runways 4/22 and 8/26

1.10.1 Airport Charts

The two main sources of airport charts that are available to the pilot community are produced by the FAA's National Aeronautical Charting Office (NACO) and Jeppesen Sanderson, Inc. Both organizations receive the information for their publications from the National Flight Data Center (NFDC),[62] which is within the FAA's Aeronautical Information Services Division.

[62] According to the FAA's Web site, the NFDC is the principal element within the FAA responsible for collecting, collating, validating, storing, and disseminating aeronautical information and detailing the physical description and operational status of all components of the National Airspace System (NAS). The NFDC maintains the national aeronautical information database and provides aeronautical information to government, military, and private producers of aeronautical charts, publications, and flight management systems. The NFDC receives information regarding changes to the NAS from other FAA offices.

The NACO chart for LEX that was current at the time of the accident was dated August 3, 2006. The chart showed the taxiway configuration at the completion of the construction project; that is, future taxiway A7 was shown on the chart, and taxiway A5 (which had been redesignated as taxiway A at the time of the accident) and taxiway A north of runway 8/26 were not shown. According to the LEX airport manager, LEX airport officials proposed that the August 3 airport chart revision show an interim airport configuration (including closed taxiway A north of runway 8/26 and former taxiway A5 redesignated as taxiway A) before the construction of taxiway A7. Because the construction schedule planned for the completion of taxiway A7 within 30 to 45 days after the repaving project was completed (August 20, 2006), airport officials expected that the NACO chart revision that followed[63] (September 28, 2006) would show the airport's final configuration. The program manager of the LEX construction project at the FAA's Memphis Airports District Office stated that he recommended against publishing an interim chart because the chart would have been inaccurate during the time both before and after the construction project.[64]

The Jeppesen chart for LEX that was current at the time of the accident was dated January 27, 2006. This chart, which was issued to the accident flight crew, showed taxiway A5 and taxiway A north of runway 8/26.[65] Jeppesen issued a revised chart for LEX on September 8, 2006.[66] As with the NACO chart for LEX, the revised Jeppesen chart showed future taxiway A7 and did not show taxiway A5 and taxiway A north of runway 8/26.[67] Appendix C shows the NACO and Jeppesen airport charts.

After the accident, Comair published a notice, dated September 8, 2006, that was appended to each dispatch release for operations to and from LEX. The notice warned, "published airport diagrams may not accurately reflect actual airport signage and markings. Exercise extreme caution during all ground operations. Utilize high threat taxi procedures.[68] If unsure of position or taxi clearance clarify with ATC or request progressive taxi instructions." The notice also specified the parts of the September 8, 2006, Jeppesen chart that were not accurate regarding the airport configuration at the time. The notice was removed from dispatch releases on November 3, 2006 (after new taxiway A7 was opened and the Jeppesen chart accurately reflected the airport configuration).

---

[63] All NACO airport charts are published on a 56-day revision cycle.

[64] An FAA official who was involved with the decision not to publish an interim airport chart stated that it was "a practice in circumstances" to recommend the publishing of an airport chart that depicts the ultimate airport configuration and that NOTAMs were to be used to advise pilots of any differences to the published charts.

[65] According to the Jeppesen flight safety manager, the Jeppesen chart did not reflect information about the LEX construction project that was received on June 23, 2006, because of a software error. (Specifically, the information was received after normal work hours on a Friday, and the software recognized only those changes that were received during the regular business week. Jeppesen has since fixed this software problem.) On August 29, 2006, Jeppesen published a corrected chart on its Web site and sent this chart electronically to its customer airlines.

[66] Even though the chart had been corrected on August 29, 2006, the official date of the revised LEX chart was September 8, 2006.

[67] Although Jeppesen publishes airport charts on a 14-day cycle, the company revises only those charts for airports where there has been a modification from the information shown on a previous chart.

[68] Section 1.17.1.1 describes these procedures.

1.10.2 Air Traffic Control

The LEX ATCT and terminal radar approach control (TRACON) provide ATC services from the surface to 10,000 feet msl within 35 nm of Lexington. ATC radar data are obtained from an airport surveillance radar-7 (ASR-7) radar at the airport.[69] The ASR-7 radar received two transponder returns (about 0606:31 and 0606:35) from the accident airplane.

About 0047 on the day of the accident, all LEX tower and radar positions[70] were combined and were being worked by one controller at the local control position. In addition, the controller was responsible for obtaining releases from the Indianapolis ARTCC's traffic management unit,[71] recording the ATIS broadcasts,[72] and performing all other required operational and administrative duties.

The controller began his employment with the FAA in October 1988 and was assigned to LEX in January 1989. He had been working at the full-performance level since the mid-1990s. The controller was required to wear glasses to correct for nearsightedness while working air traffic, and he reported that he was wearing his glasses at the time of the accident. The controller also reported that he had not experienced any operational errors during the 2 years that preceded the accident.[73]

The controller reported that his activities during the 3 days that preceded the accident were as follows:[74]

- On Thursday, August 24, 2006, at 0100, the controller finished a work shift that had started the previous day at 1700. He went to sleep between 0130 and 0145 and awoke about 0915. Afterward, he performed routine activities around the house and ran errands. He worked from 1500 to 2100,[75] returned home, and went to sleep about 2230.

---

[69] LEX was not equipped with ground radar systems such as the airport movement area safety system and the airport surface detection equipment – model X.

[70] The tower positions were clearance delivery, flight data, local control, and ground control, and the radar positions were radar departure/approach control and radar data. During his shift, the controller was also responsible for the duties of the controller-in-charge.

[71] Controllers at the LEX ATCT were required to obtain a release from the Indianapolis ARTCC's traffic management unit for all flights destined for Chicago-O'Hare International Airport, Detroit Metropolitan Wayne County Airport, and ATL.

[72] ATC recordings indicated that the controller announced a new ATIS recording every hour, approximately on the hour, during his shift.

[73] According to FAA Order 7210.56, "Air Traffic Quality Assurance," all references to a specific operational error are removed from a controller's records 2 1/2 years after the event. Also, all references to a specific operational error classified as low severity and all references to a specific operational deviation are removed from a controller's record 1 year after the event.

[74] The controller was working a "2-2-1" schedule, that is, two evening shifts, two day shifts, and one midnight shift. During a postaccident interview, the FAA's vice president for terminal services stated that the 2-2-1 schedule was the most common shift rotation used by ATC facilities.

[75] The controller was scheduled to work until 2200 but used 1 hour of annual leave at the end of his shift.

- On Friday, August 25, 2006, the controller awoke about 0715. He reported feeling good that morning. He worked from 0815 to 1615 and arrived home from work about 1630. He performed routine activities around the house, had dinner, and went to sleep about 2230.
- On Saturday, August 26, 2006, the controller awoke about 0540. He stated that he slept "very well" and that he did not feel tired. He worked from 0630 to 1430, returned home about 1445, went to sleep about 1530, and awoke between 1730 and 1800. The controller described the quality of his sleep during the afternoon as "not real good." Between 1800 and 2230, the controller's activities included eating dinner; running; visiting with friends at his home; and preparing for his next work shift, which was scheduled for 0000 to 0800 on Sunday, August 27 (the day of the accident). The controller arrived at the ATCT at 2325, signed in at 2330,[76] and relieved another controller at 2337.

The controller was the only one on duty in the ATCT from 0000 to 0640 on the day of the accident.[77] The LEX traffic count log (LEX form 7230-10) for August 27, 2006, showed that, between 0000 and 0300, 14 air traffic operations were conducted in LEX airspace. There were no aircraft operations between 0300 and 0545. The controller stated that he stayed awake during the time with no air traffic by walking inside the tower cab and listening to an AM/FM radio.[78] He recalled that, about 0545, a pilot of SkyWest flight 6819 had requested a clearance to its destination airport, which he issued. Afterward, pilots of American Eagle flight 882 and Comair flight 5191 had requested and received clearances to their destination airports.

The controller stated that, after a Comair pilot had requested and received taxi instructions, the airplane proceeded to taxiway A, which is parallel to runway 22. (By that time, both the SkyWest and American Eagle flights had departed from runway 22.) The controller indicated that he saw the lights and the tail of the Comair airplane when it was across from the parking garage.[79] Afterward, a Comair pilot told the controller that the flight was ready to depart, and the controller issued the takeoff clearance. The controller stated that he scanned runway 22 from the departure to approach ends to make sure that the runway was clear and that he scanned the digital bright radar indicator tower equipment (DBRITE) to see if there was any traffic.

The controller stated that he communicated with a pilot of the American Eagle flight and then handed off the flight to the Indianapolis ARTCC. The controller also

[76] The controller arrived 30 minutes early for his shift to earn credit time.

[77] Another controller was scheduled to begin the day shift at 0630 but was 10 minutes late reportedly because of traffic. An additional controller working the day shift was scheduled to report for work at 0700.

[78] A review of ATC tapes indicated that a radio was on during the controller's shift. According to the FAA, at the time of the accident, the use of AM/FM radios, televisions, and electronic devices were authorized in specific locations in an ATC facility, such as a break room and lounges, but facility managers had some discretion with regard to this policy. The LEX facility manager permitted the use of AM/FM radios in the tower as long as the volume level did not create a distraction that would interfere with operations. According to the latest labor contract between the FAA and the National Air Traffic Controllers Association, AM/FM radios, televisions, and similar equipment are prohibited in all operating areas.

[79] The controller stated that he noticed both the SkyWest and American Eagle airplanes at about the same point and that he also saw the American Eagle airplane at the hold short line for runway 22.

stated that he then saw the Comair airplane make a turn toward what he "presumed to be [runway] 22," which was the last time he observed the airplane. Further, the controller stated that, after he saw the airplane make this turn, he turned away from the tower cab windows (which overlooked the runway) and faced the tower cab's center console so that he could begin the traffic count (that is, a count of the hourly air traffic operations, as recorded on flight progress strips, during his shift). The controller stated that it was his common practice to place all of the flight progress strips that he accumulated throughout the night into a pile and do the traffic count all at once instead of hourly, and he estimated that the traffic count would have taken between 2 and 5 minutes to complete.[80] He recalled that, while performing this task, he heard a noise, saw fire west of the airport, and contacted the airport's operations center and airport rescue and firefighting (ARFF). Afterward, he made additional accident notifications and completed the accident checklist paperwork.

The controller stated that there was nothing unusual about the Comair flight or the clearance and that the pilots did not seem to be rushed. The controller also stated that he learned that the accident airplane had taken off from runway 26 between 1030 and 1100 after the radar data were reviewed and that he "couldn't believe it." The controller further stated that it might have been possible for him to detect that the accident airplane was on the wrong runway if he had been looking out the tower cab window. In addition, the controller stated that, in his 17 years working at LEX, an air carrier airplane had never departed from runway 26.

The controller stated that he was not experiencing any health or personal issues that would have affected his performance on the day of the accident. He stated that he did not take prescription medications or use tobacco products and that he drank alcohol occasionally. He indicated that he had not consumed alcohol during the 24 hours that preceded the accident or taken any nonprescription medication during the 72 hours before the accident. The controller also stated that during his shift he was tired but felt "fine" and "alert."[81]

The controller did not report monitoring the location and movement of the Comair airplane on the airport surface during the scans of runway 22 and the DBRITE. The controller stated that his normal work practice was to monitor airplanes during taxi and takeoff if another airplane was on final approach and he needed to ensure separation between the departing and arriving airplanes. The controller also stated that, when aircraft separation was not a factor, his decision to watch airplanes taxi and take off depended on whether he had other tasks to perform.

[80] The traffic count was accomplished by examining each flight progress strip, counting the number of strips for each category, and marking the numbers on a standardized form. The controller was required to count a total of 17 flight progress strips for this shift; 14 of the strips were for the air traffic operations conducted between 0000 and 0300, and the remaining 3 strips (for the SkyWest, American Eagle, and Comair flights) were to be counted as part of the 0600 to 0700 traffic count.

[81] The controller further stated that he "always managed to deal with" the lack of sleep during the midnight shift and that he felt "a little more tired on the mid[night] shift" compared with other shifts.

1.10.2.1 Lexington Air Traffic Control Scheduling

The LEX air traffic manager[82] stated that the LEX ATCT became a 24-hour facility in 1992 after an incident in which an airplane was cleared for a direct approach to LEX, but the pilots conducted the approach to and landed at a nearby airport.[83] In 2005, the air traffic manager prepared two studies to support closing the LEX ATCT during the midnight shift.[84]

At LEX, work hours for the day shifts were 0630 to 1430, 0700 to 1500, or 0800 to 1600; work hours for the swing shifts were 1500 to 2300 or 1600 to 0000; and work hours for the midnight shift were 0000 to 0800. The LEX air traffic manager stated that there were typically four controllers on duty during the day shifts, one controller on duty from 1000 to 1800 (in addition to the day and swing shift controllers), and five controllers on duty during the swing shifts. The midnight shift had been staffed with one controller.

On November 16, 2005, the LEX air traffic manager notified LEX ATC personnel by e-mail that, according to verbal guidance from the FAA's vice president of terminal services, facilities with radar and tower responsibilities were to be staffed with two controllers on the midnight shift so that the functions could be split, although both controllers could be colocated in the tower. According to the LEX air traffic manager, this directive was precipitated by an August 17, 2005, incident at Raleigh-Durham International Airport (RDU), Raleigh, North Carolina, which involved a loss of aircraft separation while a controller was working both the radar and tower functions.[85]

The LEX position logs for January 1 through March 31, 2006, showed that the midnight shift was staffed with two controllers for 36 of the 90 days covered by the logs.

---

[82] The air traffic manager had worked at the LEX ATCT since 1992 and had been the air traffic manager for 4 years at the time of the accident. Supervisors at the ATCT reported directly to him, and he reported to the hub manager located at CVG.

[83] In July 1987, a Delta Air Lines Boeing 737 flight crew was cleared direct to LEX for an approach to the airport. At that time, the LEX tower and radar approach control were closed. After receiving the approach clearance, the flight crew located an airport with runway lights on, entered the traffic pattern, and landed. However, that airport was Capital City Airport, Frankfort, Kentucky, with a 5,000-foot runway instead of LEX, the destination airport, with a 7,000-foot runway. (Capital City Airport is located 17 nm from LEX.) The unavailability of ATC services at LEX was included as a contributing factor to the incident. For more information, see ATL87IA201 at the Safety Board's Web site at <http://www.ntsb.gov>.

[84] The first study was an airspace reclassification study, performed during winter 2005, to support closing the LEX ATCT from 0000 to 0630 and having the Indianapolis ARTCC be responsible for the airspace during that time. In April 2006, the FAA's eastern terminal service unit indicated that additional information was needed before the airspace reclassification study could be forwarded to FAA headquarters. In July 2007, the FAA indicated that there was not a pending airspace reclassification study regarding LEX. The second study was a staff study, prepared in March 2005. This study, which was based on operational data from February 2004 to February 2005, showed that LEX did not have a sufficient traffic count (that is, 1.4 operations per hour) from 0000 to 0545 to justify ATC services during that time. As a result, the air traffic manager requested that the ATCT be closed during the midnight shift and that the Indianapolis ARTCC be responsible for the airspace during that time. The FAA's eastern terminal service unit supported this request and forwarded the study to FAA headquarters in April 2005. In July 2007, the FAA stated that the staff study, "neither constitutes a request for reclassification of the airspace at LEX, nor meets the requirements of an airspace staff study that is needed for airspace change actions."

[85] This loss of separation was resolved when the departing airplane responded to a traffic alert and collision avoidance system resolution alert.

In April 2006, the midnight shift was again staffed with one controller because traffic had increased during the day and swing shifts and the second midnight controller was needed on those shifts, according to the air traffic manager. After the accident, the midnight shift was consistently staffed with two controllers.[86] Also, on November 17, 2006, the FAA issued Notice N JO 7210.639, "Consolidating Control Functions," which modified FAA Order 7210.3, "Facility Operation and Administration," to formalize the verbal guidance from the FAA's vice president of terminal services regarding midnight shift staffing for facilities with radar and tower responsibilities.[87]

In addition, in January 2006, when the LEX ATCT was staffed with 19 controllers, the air traffic manager sent an e-mail to his hub manager, requesting that the tower be staffed with 21 controllers. At the time of the accident, the tower was still staffed with 19 controllers. In July 2007, the FAA stated that four additional controllers were hired at the LEX ATCT after the accident (two in November 2006 and two in May 2007).

1.10.2.2 Amended Takeoff Clearance Procedure

On January 4, 2007, LEX ATCT Notice N7220.124, "Runway 22 Takeoff Clearance Procedure," was issued to all LEX ATC personnel. The notice stated the following: "a takeoff clearance for Runway 22 shall not be issued until the aircraft has been physically observed having completed a crossing of Runway 26." The notice indicated that the amended procedure was "an effort to add a layer of safety … and avoid pilot confusion."

1.10.3 Taxi Demonstrations

Members of the Operations/Human Performance and Survival Factors investigative teams conducted two taxi demonstrations—one during daytime conditions and one during nighttime conditions—on the day after the accident. The purpose of these demonstrations was to observe airport features, including runways 22 and 26, taxiway A, runway and taxiway markings, lighting, and signage. The ATC investigative team observed the nighttime demonstration from the tower.

For the daytime observation, the Operations/Human Performance and Survival Factors investigative teams traveled around the airport by 15-passenger van. At the time, the weather conditions were overcast and rainy. For the nighttime observation, the Survival Factors investigative team traveled around the airport by 15-passenger van,

[86] According to the FAA, at the time of the accident, the Duluth, Minnesota, and Fargo, North Dakota, ATCTs also did not consistently comply with the midnight shift staffing policy and were combining radar and tower functions. Further, four ATCTs—located at Tulsa, Oklahoma; Kansas City, Missouri; Springfield, Missouri; and Little Rock, Arkansas—were staffed with two controllers on the midnight shift but combined the radar and tower functions. All of the facilities are now in compliance with FAA guidance.

[87] All FAA notices expire 1 year after issuance. Because the notices are temporary by nature, they are rarely renewed. According to Notice N JO 7210.639, the notice is to be in effect for 1 year or until changes are published in FAA Order 7210.3, change 3, whichever occurs first. The publication schedule in FAA Order 7210.3 indicated that submissions for change 3 were due on March 15, 2007, and that the effective date of the publication would be August 30, 2007.

and the Operations/Human Performance investigative team traveled aboard a Comair CRJ-100 airplane. At the time, weather conditions were broken to overcast clouds with no precipitation and good visibility, and the ramp, taxiway, and runway surfaces were dry. Also, the taxiway lights were on step 2,[88] and the runway 22 high intensity runway lights were on step 3, as they were at the time of the accident. (As previously stated, runway 26 had no lighting.)

The CRJ-100 demonstration airplane was positioned on the ramp near the gate from which the accident flight departed. The airplane taxied along the accident taxi route and down runway 26 to a point just past the intersection of runway 26 with runway 22; afterward, the airplane turned around and taxied down runway 26 to taxiway C and then to the ramp.[89] Next, the airplane taxied from the ramp to runway 22 using the former taxiway A5 (which had been redesignated as taxiway A at the time of the accident). After reaching runway 22, the airplane taxied down the runway to taxiway C.

During the taxi demonstration, the runway edge lights south of the intersection of runway 22 with runway 26 were dimmer on the right side than on the left side. These lights were repaired so that their intensity was returned to normal on both sides of runway 22.

Section 1.10.3.1 describes the observations made by the Operations/Human Performance investigative team from the CRJ-100 demonstration airplane, and section 1.10.3.2 describes the observations made by the ATC investigative team from the tower.

1.10.3.1 Operations/Human Performance Observations

The following observations[90] were made by the Operations/Human Performance investigative team from a CRJ-100 airplane during the nighttime taxi demonstration:[91]

At the hold short line for runway 26:

- The black and yellow taxiway location sign for taxiway A and the red and white runway holding position sign for runway 26 were visible to the left of the airplane. The signs were illuminated.
- The taxiway A yellow centerline split into three lines after the hold short position for runway 26.[92] The left centerline (referred to as a lead-on/off line) arced to the left onto the centerline of runway 26; this path was to the left of the white runway 26 numbers. The middle centerline arced slightly to the

[88] The taxiway lights had three settings, steps 1 through 3, with step 3 being the brightest.

[89] Taxiway C is shown on the airport charts in appendix C.

[90] The Survival Factors investigative team made similar observations from the 15-passenger van as it traveled around the airport.

[91] Figures 2 and 3 show the locations referenced in this section.

[92] These lines were not outlined in black, as strongly recommended, but not required, by Advisory Circular 150/5340-1J, "Standards for Airport Markings," dated April 29, 2005.

left across runway 26 to the new taxiway A (designated as taxiway A5 on the Jeppesen chart that was current at the time of the accident). The right centerline led to former taxiway A (north of runway 8/26), which was blocked by low-profile barricades with flashing red lights. [93]

- The red and white runway holding position sign for runway 22 (which was located on taxiway A on the north side of runway 26) was visible. The sign was illuminated.
- With the airplane's taxi lighting configuration (which used lights located in the wing root), the white runway 26 numbers were visible to the right of the airplane's nose. The concrete in the area around the numbers was light in color and provided relatively low contrast to the numbers.
- With the airplane's taxi lighting configuration, the taxiway A yellow centerline markings were visible but appeared darker than the surrounding area. With the airplane's takeoff lighting configuration (which included landing lights in the airplane's nose and wing root lights), the markings were visible and appeared brighter than the surrounding area.

In position on runway 26:

- White side stripes (edge markings) on runway 26 were illuminated with the airplane's takeoff lighting configuration. The markings appeared bright and reflective. With the airplane's taxi lighting configuration, the markings were visible but not as bright.
- The white centerline striping on runway 26 was visible.
- The white runway 26 numbers were positioned behind the airplane and were not visible.
- A red and white runway holding position sign for runway 4/22 was visible to the left of the airplane's nose. The sign was illuminated.
- White edge lights for runway 22 were visible.
- The 2,000-foot black and white distance-remaining marker on the right side of runway 26 was not visible.
- The end of runway 26 was not visible with the dark horizon that existed at the time.[94]
- The runway 26 surface was brighter near the airplane than it was farther down the runway.
- Blue taxiway lights were visible to the left and the right of the airplane. More lights were present on the left than on the right sides.

[93] Advisory Circular 150/5340-1J indicates that pavement markings that are no longer needed should be physically removed.

[94] Operations/Human Performance investigative team members described the view as a "black hole" except for red obstruction lights on a shack to the right of runway 26 and on radio towers on the northwest side of the airport.

In position on runway 22 at taxiway A (former taxiway A5):

- White precision runway markings were visible and illuminated with the airplane's takeoff lighting configuration. The white runway 22 numbers were visible in front of the airplane.
- White centerline striping for runway 22 was visible and illuminated with the airplane's takeoff lighting configuration.
- White edge lights for runway 22 were visible, and the brightness was balanced on the left and right sides of the runway. About 10 pairs of runway edge lights were visible. No red runway threshold lights were visible.
- White side stripes for runway 22 were visible, but their appearance was less distinct compared with the appearance of the runway 26 side stripes.
- The end of runway 22 was not visible.
- Ramp floodlights and terminal lighting were visible.

1.10.3.2 Air Traffic Control Tower Observations

During the nighttime demonstration, the airplane was clearly visible while on taxiway A between taxiway A6 and runway 22.[95] The airplane was also clearly visible when it taxied from taxiway A to runway 26, although it was difficult to determine whether the airplane was actually on runway 26 or was on runway 22 because the approach ends of both runways appeared close together.[96] As the airplane continued down runway 26 past its intersection with runway 22, the airplane's position on runway 26 became more discernible because of the lighting on runway 22. As the airplane continued farther along runway 26, it became difficult to determine whether the airplane was on runway 26 or was located on an adjacent taxiway.

When the airplane taxied from taxiway A to runway 22, it was easy to determine that the airplane was on that runway because the runway lights illuminated the airplane. Also, as the airplane proceeded down runway 22, the airplane's location became even more discernible because of the additional illumination from its landing lights, which appeared brighter than they did when the airplane was on runway 26.

The flashing red lights on the low-profile barricades located on taxiway A north of runway 8/26 were clearly visible from the tower.

[95] Taxiway A6 is shown on the August 3, 2006, NACO chart and the September 8, 2006, Jeppesen chart in appendix C.

[96] The parking garage lights provided ambient lighting, but it was not enough to distinguish the runway surface.

1.10.4 Postaccident Events

Piper PA-2 Lance Event

On November 9, 2006, a Piper PA-32 Lance was on a Part 91 flight from Shelby Municipal Airport, Shelby, North Carolina, to Logan/Cass County Airport, Logansport, Indiana, when the pilot decided to land for fuel at LEX.[97] The pilot reported that night VMC prevailed at the time.

After his airplane was refueled, the pilot began to taxi to runway 22 for takeoff. The pilot mentioned that runway 22 was lit up very well and that runway 26 was dark. He stated that, when approaching runway 22, he stopped the airplane before the runway 22 hold short line because he had to do the runup (preflight checks for airplanes with piston engines). The pilot stated that, after the runup was completed, he called the controller to report that he was ready to take off. The controller informed the pilot that the airplane was on runway 26 and instructed him to taxi the airplane onto runway 22.

The pilot stated that his airplane was on the taxiway to runway 22 at all times and that the airplane had not aligned with runway 26. The pilot also stated that, when he stopped the airplane before the runway 22 hold short line, the airplane was apparently on runway 26, which likely gave the controller the mistaken impression that the airplane would be taking off from runway 26.

Learjet 45 Event

On January 1, 2007, a Learjet 45 (Flexjet flight 428) was on a Part 91 flight from LEX to Spirit of St. Louis Airport, St. Louis, Missouri. Night VMC prevailed at the time.

The airplane was instructed to taxi to runway 22 and then was cleared for takeoff while the airplane was still on taxiway A but before it arrived at runway 26. According to the captain, he taxied the airplane across the runway 26 hold short line and made a slight left turn but did not see the taxiway to runway 22 where he expected to find it.[98] The captain stated that he then saw the taxiway to his right and that, about the same time, the first officer saw the taxiway and pointed it out. Also about the same time, the controller informed the flight crew that it looked as if the airplane were lining up on runway 26 instead of runway 22. The captain stated that the first officer told the controller that they saw the taxiway for runway 22. The captain further stated that he turned the airplane toward the right and proceeded on taxiway A to runway 22.

The captain stated that, although the airplane was on runway 26, the airplane was never lined up to take off from that runway.[99] The first officer stated that he and

[97] Before the time of this event and the next event described in this section, the construction project at LEX had been completed, so taxiway A north of runway 8/26 and former taxiway A5 (redesignated as taxiway A) no longer existed, and taxiway A7 was in use.

[98] The taxiway to runway 22 required a wider left turn and then a straight-ahead path to the runway.

[99] The captain added that it was not legal for him to take off from runway 26 because his company's policy did not allow any takeoffs from runways that were less than 4,000 feet.

the captain were not confused about the correct runway for takeoff. In addition, the first officer stated that he could not see the runway 22 approach lights, and the captain stated that he could not see the taxiway A lights, until the airplane had taxied up to the centerline of runway 26.

1.11 Flight Recorders

1.11.1 Cockpit Voice Recorder

The airplane was equipped with a Fairchild model A100S solid-state CVR, serial number (S/N) 03035. The exterior case of the CVR sustained heat and structural damage, but the interior case did not appear to have any heat or structural damage. The audio information was extracted normally and without difficulty.

The CVR was sent to the Safety Board's laboratory for readout. The CVR recording contained four channels[100] of good-quality audio data.[101] A transcript was prepared of the entire 30-minute 29-second digital recording (see appendix B).

1.11.2 Flight Data Recorder

The airplane was equipped with an L-3 Communications Fairchild Model F1000 FDR, S/N 102368. The FDR recorded flight information in a digital format using solid-state memory as the recording medium.

The FDR was sent to the Safety Board's laboratory for readout and evaluation. The FDR showed evidence of external damage as a result of the postcrash fire, but the internal components were in good condition, and the data were extracted normally. About 51 hours of data were recorded on the FDR, including about 7 minutes 46 seconds of data from the accident flight (from 0558:50 to 0606:36). Because of the damage to the airplane during the accident sequence, data recorded during the last second of data were invalid, and data for some parameters were invalid beginning 3 seconds before the end of the recording.

The accident airplane's FDR was not in compliance with the carriage requirements in 14 CFR 121.344, Appendix M. Specifically, the source of the vertical acceleration parameter was not updated at a rate that met the required recording intervals. Also, the pitch attitude parameter was recorded at a higher sample rate than the source was

[100] The first through fourth channels were the captain's station, the first officer's station, the cockpit area microphone, and the frequency shift keying timing signal, respectively.

[101] The Safety Board rates the audio quality of CVR recordings according to a five-category scale: excellent, good, fair, poor, and unusable. The Board considers a good-quality audio recording to be characterized by the following traits: most of the crew conversations could be accurately and easily understood. The transcript that was developed might indicate several words or phrases that were not intelligible. Any loss in the transcript could be attributed to minor technical deficiencies or momentary dropouts in the recording system or to a large number of simultaneous cockpit/radio transmissions that obscured each other.

updated. On May 16, 2003, the Safety Board issued Safety Recommendation A-03-15 to the FAA because of problems with the quality of FDR data recorded by several regional jet airplanes, including the CRJ. Safety Recommendation A-03-15 asked the FAA to do 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* Part 121.344, Appendix M.

The FDR installed on the Pinnacle Airlines CRJ-200 airplane that was involved in the October 2004 accident in Jefferson City, Missouri, had the same parameter problem as the FDR installed on the Comair airplane. In its final report on the Pinnacle Airlines accident,[102] the Safety Board stated that, since the time of that accident, the Board had downloaded FDR data from seven events involving CL-600-2B19 airplanes (including the Comair accident). All of these downloads showed that the FDRs recorded the vertical acceleration and pitch parameters from sources that did not meet the recording intervals required by 14 CFR 121.344, Appendix M. The Board concluded, in part, that the parameter quality problems with the FDR systems installed on CL-600-2B19 airplanes needed to be corrected so that future investigations involving these airplane models would not be hindered by inaccurate or incomplete data. As a result, on January 23, 2007, the Board reiterated Safety Recommendation A-03-15 and classified the recommendation "Open—Unacceptable Response."

1.12 Wreckage and Impact Information

1.12.1 Wreckage Site

No obvious tire marks or skid marks were found on the last 2,000 feet of the departure end of runway 26, but tire marks from the left and right main landing gear and the nose landing gear were found in the grass immediately off the end of the runway. About 130 feet off the end of the runway, the nose landing gear tire marks disappeared, but tire marks from the left and right main landing gear were still present. The left and right main landing gear tire marks continued for an additional 135 feet. Also, two ground rubs that were canted inward were found outboard of the main landing gear tire marks. These ground rubs appeared to be consistent with the main landing gear doors. A berm was located in this area.

One of the main landing gear doors was found before the berm, and a few small pieces of debris were found beyond the berm. No significant pieces of wreckage were

[102] National Transportation Safety Board, *Crash of Pinnacle Airlines Flight 3701, Bombardier CL-600-2B19, N8396, Jefferson City, Missouri, October 14, 2004*, Aircraft Accident Report NTSB/AAR-07/01 (Washington, DC: NTSB, 2007).

found until the airport perimeter fence, which was located about 380 feet off the departure end of runway 26. A perimeter fence gate that was in line with the extended centerline of runway 26 was torn from its hinges, and tire marks were found on the top of the gate.

A ground rub and two tire marks, all of which were close to the extended runway centerline, were located about 585 and 620 feet, respectively, beyond the end of the runway. One of the tire marks appeared to be made by the nose landing gear, and the other appeared to be made by a main landing gear, with about 6 feet separating the tire marks. The first sizable piece of airplane wreckage, a segment of the wing flap, was located about 750 feet beyond the end of the runway and about 70 feet to the left of the extended runway centerline.

About 900 feet beyond the departure end of the runway was the first tree strike with marks at 6 feet above ground level (agl). The tree had blue paint markings and small pieces of wreckage in the bark. A winglet tip was found forward and to the left of this tree, and the left winglet was found beyond the tree. The second and third tree strikes, with marks at 7 feet agl, were consistent with contact by the airplane at a 20° left-wing-down attitude. A section of the outboard wing was found beyond the two trees. Along the airplane's groundpath and about 35 feet beyond the three trees were 10 additional trees that were sheared off at about the same level but at an increasing height (12 feet agl) because the ground sloped downward after the first tree. Minor fire damage was observed on the third through ninth trees. Ground scars appeared about 400 feet beyond the first tree strike. Fire damage to the ground and four trees in this area was observed. The main wreckage was found about 900 feet beyond the first tree strike and about 1,800 feet west of the departure end of runway 26.

1.12.2 Airplane Wreckage

The fuselage had separated into two main sections, and both wings had separated from the fuselage. The left and right engines remained attached to the aft fuselage. The empennage had separated from the aft fuselage. The left and right main landing gears had separated at their respective airframe attachment points, but part of the nose landing gear remained attached to the airframe.

Impact forces and postcrash fire damaged the main avionics compartment and the components that were installed in the compartment. All of the primary and secondary flight control systems were identified in the wreckage, but the impact damage to the systems prevented an examination of flight control cable continuity.

The main cabin door was closed and intact in the door frame. The exterior of the door was blackened by heat, and the interior of the door and the interior door handle were consumed by fire. The four latch pins were engaged in the door frame in the closed position. The forward service door was closed, and the unburned portion was intact in the door frame. The exterior door handle was in the closed position, and the interior door handle, which was partially consumed by fire, was also in the closed position. The

left overwing exit[103] was found within the main cabin debris area on the right side of the main wreckage area. The exit release handle was in its closed position. The spring-loaded securing pins were extended. Portions of the right overwing exit frame and window exit were found in a pile of wreckage near their approximate position in the fuselage. The spring-loaded securing pins were found extended.

A portion of the captain's seat frame was found fragmented and burnt about 15 feet to the left of the cockpit area. The first officer's seat was found in the cockpit separated into two pieces. The flight attendant jumpseat and the passenger seats and restraint systems were severely damaged or destroyed by impact forces and postcrash fire.

1.13 Medical and Pathological Information

The Fayette County Coroner's office examined the remains of the captain, flight attendant, and passengers. Their cause of death was "multiple injuries sustained in a commercial aviation crash with subsequent fire." The major pathologic findings for these airplane occupants are shown in figure 4 along with injury information for the first officer.

Toxicology tests were performed by the FAA's Civil Aeromedical Institute (CAMI) on specimens from the captain and the first officer. Tissue specimens from the captain tested negative for ethanol and a wide range of drugs, including major drugs of abuse. In addition, the captain's postmortem examination identified a contact lens over the left eye. Blood from the first officer[104] tested negative for ethanol and a wide range of drugs, including major drugs of abuse, except that a low amount of pseudoephedrine was detected.[105]

The controller took a drug and alcohol test[106] at 1330 on the day of the accident in accordance with 14 CFR 65.46, "Use of Prohibited Drugs."[107] The results were negative.

[103] The overwing exits are located at row 8 (see figure 4 in section 1.13).

[104] The specimen from the first officer was collected at 0656 on the day of the accident.

[105] Pseudoephedrine is a decongestant that is available without a prescription in various preparations that are marketed for the treatment of cold or allergy symptoms. The captain who flew with the first officer on August 25 and 26, 2006, stated that the first officer showed no indication of a cold or an allergy during their flights.

[106] A urine specimen was tested for the presence of alcohol and five drugs: marijuana, cocaine, phencyclidine, amphetamines, and opiates.

[107] According to the FAA drug testing project manager, drug and alcohol testing is mandatory after any fatal accident, and the testing should be complete within 8 hours of the accident.

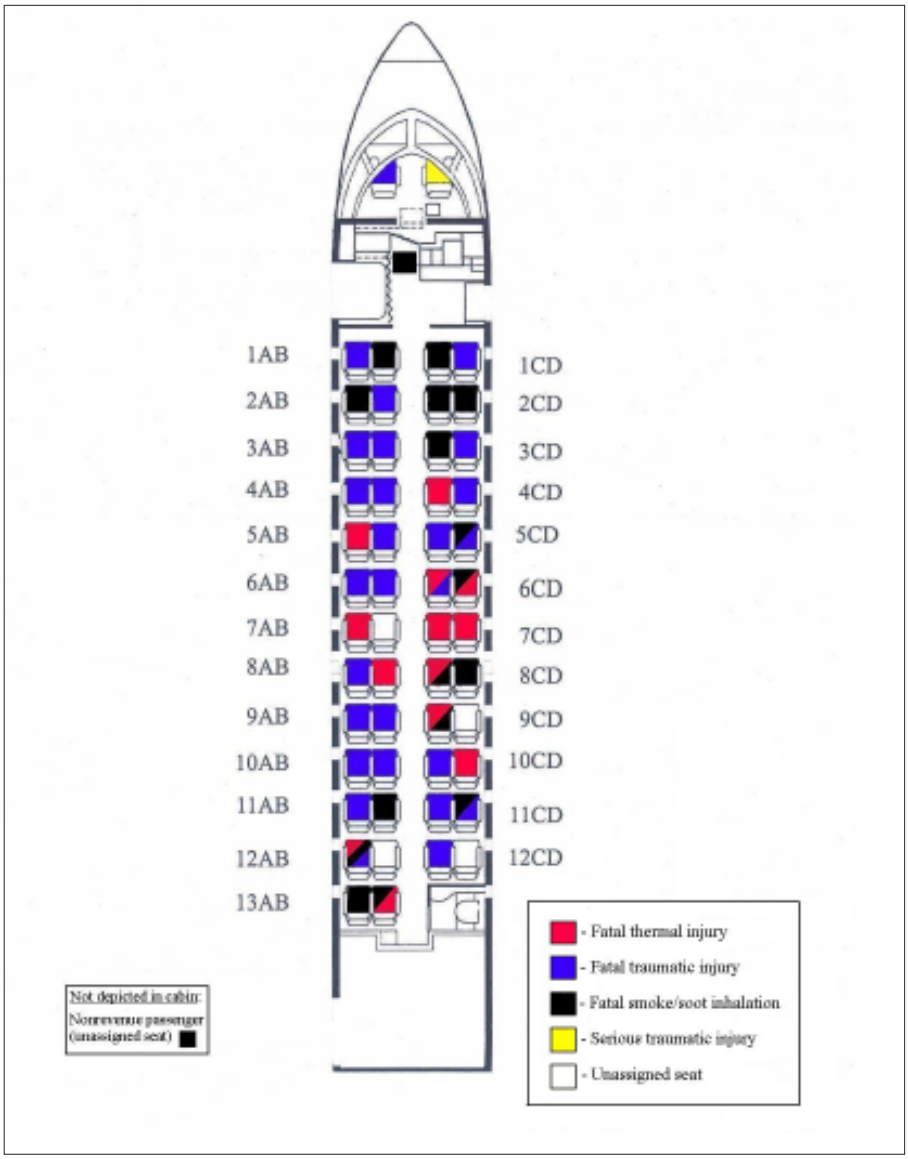


Figure 4. Injury Information According to Seat Assignment

Note: Seat positions showing more than one color indicate more than one reported major pathologic finding in the autopsy reports.

Note: The nonrevenue passenger (who was deadheading to ATL) is not depicted in the cabin because he was not assigned a seat.

1.14 Fire

The airplane wreckage showed no evidence of a preimpact fire. The wreckage showed postcrash fire damage.

1.15 Survival Aspects

The first officer, the only survivor of the accident, received serious, life-threatening blunt force injuries. He was rescued from the cockpit wreckage and was immediately transported to the University of Kentucky Hospital in Lexington. The first officer was discharged to a rehabilitation facility on October 13, 2006, where he remained until December 15, 2006.

1.15.1 Emergency Response

A LEX public safety officer[108] and a city of Lexington police officer[109] were the first to arrive at the accident site. According to radio transmission audio recordings from the LEX operations center, the LEX public safety officer arrived on scene about 5 1/2 minutes after receiving alert 3 notification and located the fuselage about 3 1/2 minutes later. He and the police officer from the city of Lexington were able to free the first officer from the cockpit wreckage. Another LEX public safety officer arrived on scene while the first officer was being extricated. This LEX public safety officer used his sport-utility vehicle to transport the first officer to the hospital rather than wait for an ambulance.[110] This LEX public safety officer estimated that they arrived at the hospital (located about 7 miles from the accident site) before 0630.

Two 3,000-gallon ARFF vehicles responded to the accident. To reach the accident site, the ARFF vehicles traveled about 2 1/2 miles from the ARFF station by way of public roads, a dirt road with a significant incline, and off-road terrain. The first ARFF vehicle to arrive on scene arrived about 11 minutes after the alert 3 notification and began fire suppression immediately using its high-flow turret to knock down most of the fire followed by the bumper turret and handlines for additional fire suppression. This ARFF vehicle had been directed to the location of the accident by a LEX public safety officer. The second ARFF vehicle to arrive on scene began additional fire suppression using its high-reach extendable turret.[111] The LEX operations center incident report showed that the fire was controlled within about 3 minutes.

[108] LEX public safety officers are cross-trained as police officers, firefighters, and emergency medical technicians.

[109] City of Lexington police officers were notified of the accident by the police department's dispatcher, who had received emergency calls from citizens.

[110] The city of Lexington police officer traveled in the back of the sport-utility vehicle with the first officer.

[111] The high-reach extendable turret was equipped with a forward-looking infrared camera. The operator of this ARFF vehicle did not activate the camera during the emergency response. After the accident, the camera system was modified so that it would activate at the time of engine start.

1.16 Tests and Research

1.16.1 Aircraft Performance Study

The Safety Board performed an aircraft performance study for this accident. FDR and CVR data were time correlated. The latitude and longitude data recorded on the FDR, however, were not sufficient to determine the airplane's exact position. As a result, the Board developed a time history of the accident airplane's motion to identify the position of the airplane in the context of the transmissions recorded on the CVR. To develop the time history, the Board integrated acceleration and attitude data from the FDR and combined the results with wind and atmospheric data at the time of the accident, airport information, and wreckage documentation.

FDR data showed that the airplane began to taxi about 0602:17, about 2 1/2 minutes after the flight crew initiated the pushback from the gate. FDR data also showed that the airplane was stopped at the hold short line for runway 26 from about 0604:33 to about 0605:23 and that the airplane had taxied across the runway 26 hold short line about 0605:24.[112] In addition, FDR data showed that the airplane aligned with the runway 26 centerline about 0606:00 and began the takeoff roll about 0606:06. The aircraft performance data (V_1, V_R, and V_2)[113] referenced in the flight paperwork and recorded on the CVR assumed a takeoff on runway 22.

The airplane impacted a berm (located about 265 feet from the end of runway 26) about 0606:32. FDR airspeed and altitude data showed that the airplane became temporarily airborne after impacting the berm but climbed less than 20 feet off the ground. Less than 1 second after impacting the berm, the airplane impacted the airport perimeter fence (located 380 feet from the end of runway 26) and experienced a vertical load factor of at least 2.5 Gs at that time.[114] FDR airspeed and altitude data showed that the airplane accelerated about 4.3 knots per second from the time of the takeoff roll to the time that the airplane impacted the airport perimeter fence. About 0606:35, the airplane impacted the first tree (located about 920 feet from the end of the runway) and experienced a vertical load factor of at least 4.0 Gs.

1.16.2 Takeoff Distance and Accelerate-Stop Calculations

Bombardier provided the Safety Board with accelerate-stop performance calculations for runway 26. These calculations showed the point beyond which a CRJ-100 could not be stopped on the available runway, even with maximum braking applied. For the airplane to stop before the end of runway 26, maximum braking would have had to start when the airplane was at an airspeed of 103 knots. This speed would be reached

[112] The airplane did not stop again along the remaining taxiway or the runway.

[113] V_2 is the takeoff safety speed.

[114] G is a unit of measurement that is equivalent to the acceleration caused by the earth's gravity (32.174 feet/second^2).

when the airplane was 1,834 feet down runway 26, leaving 1,667 feet for stopping on the runway.

In addition, Bombardier calculated that a CRJ-100 would need 3,593 feet to reach a V_1 speed of 135 knots[115] and 3,744 feet to start rotation.

1.17 Organizational and Management Information

Comair, Inc., was founded in 1977 and provided service initially to and from Cincinnati, Cleveland, and Akron-Canton, Ohio. In 1984 Comair became a Delta Connection air carrier. In 1993 the company began to transition from turboprop[116] to turbojet airplanes with the addition of 40- and 50-passenger seat CRJs to its fleet. In January 2002 Comair became a wholly owned subsidiary of Delta Air Lines. In 2002 Comair added the 70-passenger-seat CRJ to its fleet and became an all-turbojet operation.

Comair has its headquarters in Erlanger, Kentucky. At the time of the accident, the company served 97 cities in the United States, Canada, and the Bahamas, with an average of 772 flights per day, and employed more than 6,400 personnel, including 1,631 pilots (825 captains and 806 first officers).

1.17.1 Flight Manuals

1.17.1.1 Taxi Procedures and Briefing

The Comair Operations Manual, chapter 4, section 4.4.1, page 4-23, "General Taxi Procedures," dated September 1, 2005,[117] stated that, before taxi, the captain should perform the taxi briefing and that, during taxi, the captain should verbalize the essential elements of taxi clearances received, emphasizing runway crossings. This section also stated that both flight crewmembers should monitor the progress of the taxi by utilizing the horizontal situation indicators (HSI), airport diagrams, and airport signage to confirm positions. Further, this section stated that, in the event that a taxi clearance would take the airplane into a part of the airport that was not briefed or if either flight crewmember lacked complete understanding of the taxi clearance, the crew should stop the taxi, refer to the airport diagram, and query ATC if required.

Section 4.4.2, page 4-23, "Taxi Briefing," stated that the captain's taxi briefing was to include Comair standard taxi information. This information was to be briefed in its

[115] As previously stated, the V_1 speed according to Comair was 137 knots. A difference existed between Comair's and Bombardier's V_1 speeds because Comair computed V speeds using interpolations for airplane weight and atmospheric conditions (altitude and temperature), whereas Bombardier computed V speeds using the exact airplane weight and atmospheric conditions.

[116] The company had operated the Piper Navajo, Piper Chieftain, Embraer EMB-110, Shorts 330, Fairchild SA-227, Saab 340, and Embraer EMB-120 turboprop airplanes.

[117] All of the taxi procedures in this section were dated September 1, 2005.

entirety for the first flight as a crew and could be abbreviated to "Comair standard" for subsequent flights. The Comair standard taxi information included the following:

- Both flight deck crewmembers will have appropriate airport diagrams out and available.
- Complicated or unexpected clearances shall be written down.
- Traversing runways … requires extra vigilance.
- If unsure of position or instructions … clear any runways, stop, and call ATC.

Section 4.4.4, page 4-25, "Airport/Field Taxi," stated that, when clear of the ramp, the captain should verbalize the essential elements of the taxi clearance, placing special emphasis on runway crossings.

Section 4.5.5, pages 4-27 and 4-28, "High Threat Taxi Procedures," stated that flight crews were to use high threat taxi procedures when the operating environment presented "exceptional" hazards to safe taxi and that these procedures were to be used "when the captain deems the operation requires exceptional vigilance." The section also stated that, during these operations, both pilots were to be heads-up during airplane movement and that they should monitor the taxi and hold short locations. In addition, the section stated, "both pilots must be familiar with the assigned taxi route before aircraft movement. If in doubt, remain clear of all runways and contact ATC."[118]

1.17.1.2 Checklist Usage

The Comair CRJ Flight Standards Manual, volume I, chapter 3, sections 3.7.3 and 3.7.6 through 3.7.8, pages 3-60, 3-74, 3-76, and 3-78, dated November 30, 2005, stated that the first officer was to perform the before starting engines, taxi, before takeoff, and lineup checklists. These checklists contained challenge and response items, which were read by the first officer and responded to by the captain, and verbal response items, which were verbalized by the first officer.

The manual also stated that the captain was to call for the taxi, before takeoff, and lineup checklists but did not specifically mention which crewmember was to call for the before starting engines checklist. According to Comair, although either pilot can call for the before starting engines checklist, the captain typically calls for it.

[118] Comair used "pink sheets" to supplement airport information shown on Jeppesen charts. The pink sheets contained operational procedures and recommendations, including the use of high threat taxi procedures when appropriate, for a specific airport. A pink sheet had not been issued for LEX at the time of the accident.

1.17.1.3 Sterile Cockpit Procedures

The Comair Operations Manual, chapter 5, section 5.13.2, pages 5-61 and 5-62, "Critical Phases of Flight/Sterile Cockpit," dated December 1, 2005, stated the following:[119]

> Critical phase of flight includes all ground operations involving taxi, takeoff and landing, and all other flight operations conducted below 10,000 ft, except cruise flight. Taxi is defined as 'movement of an aircraft under its own power on the surface of an airport.'
>
> No flight crewmember shall perform any duties during a critical phase of flight except those duties required for the safe operation of the aircraft.
>
> No flight crewmember may engage in, nor may any pilot-in-command permit, any activity during a critical phase of flight which could distract any flight crewmember from the performance of his duties or which could interfere in any way with the proper conduct of those duties … such as … engaging in nonessential conversations within the flight deck.

1.17.1.4 Heading Bugs

The Comair CRJ Flight Standards Manual, volume I, chapter 3, section 3.7.3, page 3-63, "Before Starting Engines," dated November 30, 2005, stated that flight crewmembers should set course selectors and heading bugs. Volume II of the manual, chapter 7, section 7.3.4, "Heading Bug," dated November 30, 2005, stated that, on departure, if a turn is required at or below 400 feet agl, the heading bugs should be set to the heading required by ATC, the departure procedure, or the runway heading. This section also stated that, if a straight-out departure is planned or a turn is required by departure procedures above 400 feet agl, the heading bugs should be set to the runway heading.

1.17.1.5 Normal Takeoff

The Comair CRJ Flight Standards Manual, volume II, chapter 7, section 7.4.4, pages 7-14 and 7-15, "Normal Takeoff," dated November 30, 2005, stated that the nonflying pilot was to call "V_1" and "rotate" as appropriate. The section also stated that the V_1 callout should be made so that, upon reaching V_1, the callout would be completed. In addition, the section stated that, at V_R, the flying pilot should rotate the airplane smoothly toward the target pitch attitude in one continuous motion at a rate of about 3^o per second.

1.17.1.6 Use of Alcohol

The Comair Operations Manual, chapter 3, section 3.11, page 3-26, "Intoxicants and Illicit Drugs," dated June 10, 2005, stated that a certificated airman would be subject to

[119] These procedures were in accordance with 14 CFR 121.542, "Flight Crewmember Duties."

termination if the airman consumed any alcohol within 12 hours of scheduled departure. (Title 14 CFR 121.458(d)(1) states that pilots may not perform flight crewmember duties within 8 hours of consuming alcohol.)

1.17.1.7 Flight Crew Rest Periods

The Comair Operations Manual, chapter 3, section 3.8.3, page 3-18, "Flight Time Limitations and Rest Requirements," dated June 10, 2005, stated that a pilot's rest period begins 20 minutes either after actual block in or the last scheduled airplane movement or when actually released, whichever is later. This section also stated that the rest period at a field location ends when the crewmember reports to the gate or operations center (45 minutes before departure or 30 minutes before departure if necessary because of transportation). Further, the section stated that transportation to and from a local hotel is considered to be part of the rest period.

Page 3-20 described the following rest requirements for pilots, which were based on the number of scheduled flight hours in the preceding 24 hours of the planned completion of each flight segment:[120]

- For a scheduled flight time of less than 8 hours, the required rest in between flights is 9 hours.
- For a scheduled flight time of between 8 and 9 hours, the required rest in between flights is 10 hours.
- For a scheduled flight time of 9 or more hours, the required rest in between flights is 11 hours.

1.17.1.8 Crew Resource Management

The Comair Operations Manual, chapter 5, section 5.6.1.2, page 5-20, "Crew Resource Management," dated May 15, 2005, stated that the captain was responsible for the CRM concept of "authority with participation." This section also stated that the captain was responsible for providing leadership but would also elicit and welcome participation from other crewmembers during the conduct of a flight.

This section further stated that the first officer was responsible for the CRM concept of "assertiveness with respect." In addition, this section stated that the first officer would be an integral participant in the safe conduct of a flight and that the first officer would interact with the captain in a positive, consistent manner while still honoring the captain's position.

[120] These requirements were in accordance with 14 CFR 121.471(b).

1.17.2 Crew Resource Management Training

As part of their initial training at Comair, the flight crewmembers received two 8-hour classes in basic CRM training, a 4-hour class in command leadership, and a 2-hour class in CRM in automation. At the time of the accident, new captains received an additional 3-hour class in command leadership and an additional 2-hour class in CRM in automation during their upgrade training. Also, Comair provided a 2-hour "common day" class with pilots, dispatchers, and flight attendants in the same class.

In addition, Comair provided CRM training during 2-hour modules in each recurrent training cycle. The topics presented during recurrent CRM training included teamwork, communication, decision-making, situational awareness, and workload management. The course referenced industry CRM guidance, accidents and incidents that occurred at Comair and other air carriers, and Safety Board reports and studies. The information was presented through lectures and interactive discussions based on event scenarios.

Each CRM recurrent training module contained specific areas of emphasis. For example, the 2006 CRM module focused on managing errors and understanding how selective attention and selective noncompliance could increase the likelihood of an error. Also, the 2005 CRM module focused on understanding and managing the risks associated with daily operations and mitigating these risks by applying good decision-making and team-building skills. In addition to the CRM training modules, CRM skills were evaluated during simulator training, line-oriented evaluations, and checkrides.

During a postaccident interview, a CRM facilitator instructor (who was also a check airman) stated that the CRM training at Comair was excellent. The instructor also stated that Comair's culture encouraged first officers to speak up if a captain has made an error and that this aspect of CRM was reinforced during flight training. The instructor further stated that, when first officers have not spoken up during line checks after a captain has made an error, it was because of a lack of situational awareness rather than a hesitancy to speak up.

Comair captains described CRM training as good. Comair first officers stated that they had no difficulties speaking up if they felt rushed or had concerns with the conduct of the flight. Also, the principal operations inspector (POI) for Comair stated that there had not been a crew interaction problem during the 5 years that preceded the accident.

1.17.3 Safety Program Personnel Initiatives

At the time of the accident, Comair's corporate compliance committee (which comprised the officers and the president of the company) met at least quarterly to review safety performance metrics and progress in achieving the company's safety initiatives.

The director of corporate safety reported to the corporate compliance committee. A flight safety specialist, an aviation safety action program (ASAP)[121] coordinator, and two ASAP analysts reported to the director of corporate safety.

Comair initiated action before the accident to create the position of manager of flight safety, but the change to the organizational structure did not occur until the week after the accident. The manager of flight safety reports to the director of corporate safety, and the flight safety specialist, ASAP coordinator, and two ASAP analysts now report to the manager of flight safety. The director of corporate safety stated that flight safety department staff provided briefings during initial and recurrent ground schools and worked closely with the training department to ensure that flight safety trends, such as navigation or altitude deviations, were addressed.

Comair's written safety policy is published in multiple locations, including the employee Web page and the corporate program safety manual. Pilots receive flight-specific safety information through the dispatch release. Pilots receive other relevant flight safety information through communications on bulletin boards; the quarterly safety newsletter; and "Ops Notes," which are one-page safety reports.

One way Comair pilots can communicate flight safety concerns is through irregular operations reports, which are transmitted to flight operations managers; the corporate safety department; and the flight safety department, which tracks and evaluates them. Another way that pilots can communicate such concerns is through Comair communications logs, which are sent to and reviewed by the flight safety department.

In addition, another way that pilots can communicate flight safety concerns is through the company's ASAP. From May 2004 to July 2006, the company received more than 2,400 ASAP reports.[122] The company's ASAP event review committee meets weekly to review ASAP reports. According to Comair, no reports had been received describing circumstances related to those of the accident. In addition, the flight safety department reviews ASAP and irregular operations reports to monitor trends, and the information learned from these reviews is presented at quarterly flight safety committee meetings. Deviations that are identified through this process are evaluated so that recommendations can be proposed to reduce the deviations.

The director of corporate safety stated that the company was working toward implementation of a flight operations quality assurance (FOQA) program[123] by the end of 2008. The director also stated that the company was examining FAA Advisory Circular

[121] An ASAP is an FAA-approved, voluntary safety program that encourages pilots to report safety concerns in a nonpunitive environment, which allows the air carrier and the FAA to act on this information before an accident or an incident occurs. An ASAP depends on the willingness of pilots to voluntarily submit reports about other pilots or themselves. Comair's ASAP for pilots began in May 2004.

[122] Comair's ASAP included dispatchers, and the company was working to add maintenance personnel to the program. An ASAP can also include flight attendants.

[123] A FOQA program is an FAA-approved, voluntary program for the routine collection and analysis of FDR data gathered during aircraft operations.

(AC) 120-92, "Introduction to Safety Management Systems [SMS] for Air Operators"[124] (issued in June 2006), and was moving toward implementing an SMS program.[125] In addition, the director stated that Comair was working on a Line Operations Safety Audit (LOSA) program;[126] had contracted with the University of Texas at Austin, which developed the program in 1994 through FAA-sponsored research known as the Human Factors Research Project; and was awaiting the support of the company's local pilot union.

Comair's corporate safety and compliance departments prepare monthly safety performance and compliance reports, which include monthly data showing the number of runway incursions reported during the previous 12 months and brief statements describing those incursions that occurred during the previous month. For the 12-month period ending July 2006, Comair reported 21 runway incursions. None of these incursions involved a takeoff from the wrong runway.

1.17.4 Federal Aviation Administration Oversight

The FAA certificate management office for the Comair certificate is located in Atlanta, and the certificate management unit (which handles oversight) is located in Louisville, Kentucky. The POI and assistant POI for Comair had been in their positions for about 3 1/2 and 2 years, respectively, at the time of the accident. The certificate management unit also included two aircrew program managers and a cabin safety inspector.

At the time of the accident, the FAA conducted its oversight of Comair through the air transportation oversight system (ATOS).[127] The Safety Board's review of ATOS records showed that the FAA had conducted more than 120 inspections at Comair

[124] An SMS program incorporates proactive safety methods for air carriers to identify hazards, mitigate risks, and monitor the extent that air carriers are meeting their objectives. Program components include safety policy, safety risk management, safety assurance, and safety promotion.

[125] On January 23, 2007, as a result of its investigation of the Pinnacle Airlines flight 3701 accident, the Safety Board issued Safety Recommendation A-07-10, which asked the FAA to "require that all 14 *Code of Federal Regulations* Part 121 operators establish Safety Management System programs." On April 13, 2007, the FAA stated that it began a rulemaking project to meet the International Civil Aviation Organization's deadline of January 1, 2009, for SMS requirements. The FAA also stated that pilot project trials had been scheduled to better address issues related to SMS implementation.

[126] The LOSA program is an observational process that assesses CRM practices, the management of threats to safety, and human error during flight operations. Trained personnel associated with the project conduct line observations under conditions of confidentiality so that the operator is provided only with details of the observations and no information about the pilots who were involved. As a result, in contrast to a company line check, LOSA observations do not result in adverse actions against pilots who did not perform well during their observation. Also, LOSA observations have identified rule violations and deviations from procedures, which suggested that the pilots being observed did not view the LOSA observers as a threat and would be likely to perform in the same manner as they would without an observer present.

[127] In 1998, the FAA established ATOS, which employs a systems safety approach to air carrier oversight. The benefits of the ATOS program's system safety approach to air carrier oversight include a more integrated approach to oversight that better identifies risks to system safety and a more effective allocation of oversight resources to problem areas. Comair became an ATOS carrier in June 2006; before that time, the FAA conducted its oversight of the company under the National Program Guidelines. The guidelines, which have been in effect since 1985, are part of a traditional inspection program to ensure that airlines comply with safety regulations.

between June 2006 and the time of the accident and that the results of these inspections were satisfactory. The POI stated that Comair anticipated the oversight system changeover and, as a result, had reviewed its processes to determine how they would align with ATOS inspection checklists.

1.18 Additional Information

1.18.1 Witness Information

The two eyewitnesses to this accident were interviewed by the Safety Board. One eyewitness was an American Eagle station agent who was on a ramp by a gate when the accident airplane taxied past his location at a normal taxi speed. The station agent stated that he saw the airplane make a sharp, instead of a slight, turn to the left. He thought the flight crew might have made this turn so that the airplane could return to the gate. The station agent was not paying attention to the airplane when its engine power increased, but he then realized that the airplane was taking off from runway 26. He saw the airplane continue down the runway but did not notice if the nose of the airplane rose. The station agent then saw and heard an explosion followed by some "pops" and three or four smaller explosions. Also, he stated that the runway 22 lights and taxiway lights were illuminated.

The other eyewitness to the accident was a resident of the living quarters portion of a horse trailer located on property near the airport. He was at home when he heard a "freight train" sound. He then looked outside and saw the accident airplane's landing lights coming toward him. He saw the airplane strike the ground once or twice before becoming airborne and striking a group of trees on the property. He estimated that the airplane was about 10 feet in the air when it struck the first trees. He stated that he was not able to see the airplane after it struck the trees because horse barns on the property obstructed his view but that he was able to see fire and smoke at that point.

1.18.2 Related Federal Aviation Administration Guidance

1.18.2.1 Advisory Circular 120-74A

AC 120-74A, "Parts 91, 121, 125, and 135 Flightcrew Procedures During Taxi Operations," dated September 26, 2003, contained guidelines for establishing standard operating procedures to promote safe aircraft ground operations. In a section addressing crew verbal coordination on the flight deck, AC 120-74A states, "before entering a runway for takeoff, the flightcrew should verbally coordinate to ensure correct identification of the runway and receipt of the proper ATC clearance to use it." Appendix 2 of AC 120-74A contained information about runway incursion prevention and recommended that flight crews "verify that the compass heading approximately matches the runway heading and taxiway orientation" to confirm proper runway or taxiway selection. Appendix 4 of AC 120-74A contains recommended normal procedures for surface

operations and departure and states that, after being cleared onto the active runway, the flight crew should "verbally confirm ATC clearance onto [the] active runway with other crewmembers and confirm proper runway selection using airport signs and markings and the airport diagram." Appendix 4 also states that, when the airplane is at the takeoff end of the runway, the flight crew should "confirm proper runway selection using [the] HSI."

1.18.2.2 Safety Alert for Operators 06013

On September 1, 2006, the FAA issued Safety Alert for Operators (SAFO)[128] 06013, "Flight Crew Techniques and Procedures That Enhance Pre-takeoff and Takeoff Safety," which discussed techniques, procedures, and items for consideration for training programs that emphasize safe operations in the pretakeoff and takeoff phases of flight. The SAFO provided reminders of existing FAA guidance on ground operations, such as AC 20-74A, and stated that flight crews should "confirm, using the challenge and response technique, that the aircraft is actually positioned on the assigned runway by reference to the heading indicator." Also, the SAFO recommended that pilots "use all available resources to ensure that the aircraft is positioned on the proper runway" and that flight crews of flight management system (FMS)-equipped airplanes "verbally announce that the proper runway and departure procedure are selected in the FMS and that the aircraft heading agrees with the assigned runway for takeoff."

1.18.2.3 Certalert 07-01

On January 9, 2007, the FAA issued Certalert 07-01,[129] which suggested that airport operators supply detailed information about runway and taxiway closures and airport construction to air carriers and fixed-base operators on the airport. The certalert indicated that this information should be provided both textually and visually. To provide this information visually, the certalert suggested that airport operators create diagrams that pinpoint the exact location of any runway or taxiway closures and disseminate the diagrams by e-mail, through a Web site, or by hand delivery.

1.18.2.4 Takeoff Clearance Notice

On June 1, 2007, the FAA issued Notice N JO 7110.468, "Takeoff Clearance," to amend the required phraseology for issuing aircraft departure instructions. The notice included the following procedures: "when issuing a clearance for takeoff, first state the 'runway number followed by the takeoff clearance'" and "if the takeoff clearance is issued prior to the aircraft crossing all intervening runways, restate the runway to be crossed in conjunction with the takeoff clearance." The notice indicated that this information would be incorporated into FAA Order 7110.65 on February 14, 2008.

[128] FAA Order 8000.87, dated August 29, 2005, established SAFOs and stated, in part, that SAFOs conveyed "new important safety information" directly to operators as that information became available but that SAFOs were not mandatory.

[129] Certalerts are advisory and cautionary in nature.

1.18.3 Previous Related Safety Recommendations

1.18.3.1 Flight Crew Operations

Safety Recommendation A-89-15

On March 24, 1989, the Safety Board issued Safety Recommendation A-89-15 (urgent) as a result of two incidents of pilot deviation that involved departures of U.S. air carrier airplanes from the wrong runway at Houston Hobby Airport (HOU), Houston, Texas.[130] Safety Recommendation A-89-15 asked the FAA to do the following:

> Take immediate corrective action, in conjunction with the airport authority, to prevent inadvertent takeoffs by air carrier airplanes on runway 17 at the Houston Hobby Airport.

On May 1, 1989, the FAA stated that it and the HOU airport authority had posted additional guidance signs and issued NOTAMs regarding the closing of runway 17 and instructions for taxiing to runway 12R (which intersected runway 17 near the approach end of the runway). On the basis of these actions, the Safety Board classified Safety Recommendation A-89-15 "Closed—Acceptable Action" on July 12, 1989.

Safety Recommendation A-89-74

Although the Safety Board believed that the actions taken by the FAA and the HOU airport authority were responsive toward eliminating additional inadvertent departures from runway 17 at HOU, the Board was concerned about preventing similar incidents at other airports. The Board thought that the incidents at HOU could have been prevented if the flight crews had compared their heading indicators with the runway heading as the crews aligned their airplanes with the runway centerline. Also, in its final report on the December 23, 1983, accident involving Korean Air Lines flight 84 and South Central Air flight 59, the Board found that the Korean Air Lines airplane was on the wrong runway and that the flight crewmembers could have made this determination if they had compared their heading indicator with the runway heading.[131] As a result, on July 17, 1989, the Safety Board issued Safety Recommendation A-89-74, which asked the FAA to do the following:

> Assure that the 'Normal Procedures' section of the operations manuals of all air carriers operating under Title 14 *Code of Federal Regulations* Parts 121 and 135 requires flightcrews to cross-check the heading

[130] The first incident occurred on January 10, 1989, when Eastern Airlines flight 536, a McDonnell Douglas DC-9, struck barricades on rotation during the takeoff roll from runway 17 (which had been closed because of construction) and overflew workers and equipment. The flight continued to its destination without further incident. The second incident occurred on March 23, 1989, when American Airlines flight 508, a McDonnell Douglas MD-82, struck a barricade on rotation during the takeoff roll from runway 17 (which was still closed). The flight continued to its destination without further incident.

[131] For more information, see National Transportation Safety Board, *Korean Air Lines, McDonnell Douglas DC-10-30, HL 7339, South Central Air Piper PA-31-350, N35206, Anchorage, Alaska, December 23, 1983*, Aircraft Accident Report NTSB/AAR-84/10 (Washington, DC: NTSB, 1984).

> indicator to the runway heading when the airplane is aligned with the runway for takeoff.

On September 28, 1989, the FAA stated that almost every Part 121 and 135 air carrier had incorporated the recommended procedure into their before takeoff checklist. Nevertheless, the FAA stated that it planned to revise Air Carrier Operations Bulletin (ACOB) 8-85-1, "Crewmember Procedures and Responsibilities During Ground Operation in Restricted Visibility Conditions,"[132] to address this procedure. On August 22, 1990, the FAA stated that it revised ACOB 8-85-1, to address the cross-check of the heading indicator to the runway heading when an airplane is aligned with the runway for takeoff. As a result of this action, the Safety Board classified Safety Recommendation A-89-74 "Closed—Acceptable Action" on December 11, 1990.

Safety Recommendations A-06-83 and -84

On December 12, 2006, the Safety Board issued Safety Recommendations A-06-83 and -84 after identifying that multiple Part 121 operators (including Comair) did not have procedures for positively verifying that an airplane is aligned on the correct departure runway[133] and learning that some Part 121 operators (including Comair) did not provide guidance to their pilots about conducting takeoffs at night on unlighted runways.[134] Safety Recommendations A-06-83 and -84 asked the FAA to do the following:

> Require that all 14 *Code of Federal Regulations* Part 121 operators establish procedures requiring all crewmembers on the flight deck to positively confirm and cross-check the airplane's location at the assigned departure runway before crossing the hold short line for takeoff. (A-06-83)

> Require that all 14 *Code of Federal Regulations* Part 121 operators provide specific guidance to pilots on the runway lighting requirements for takeoff operations at night. (A-06-84)

The FAA responded to these recommendations on March 13, 2007. With regard to Safety Recommendation A-06-83, the FAA stated that it intended to issue a SAFO

[132] As part of its investigation into the accident, the Safety Board issued Safety Recommendation A-84-102, which asked the FAA to "require that air carriers incorporate in training of their crewmembers procedures and responsibilities during ground operations in restricted visibility conditions to enable them to operate safely in such conditions." In response, the FAA issued ACOB 8-85-1 in May 1985. The Board classified Safety Recommendation A-84-102 "Closed—Acceptable Action" on September 12, 1985.

[133] On March 23, 2007, Comair revised its operations manual to include a section titled, "Departure Runway Check." This section states the following: "when taxiing onto the runway for departure, both flight crewmembers must check airplane heading to ensure that the heading corresponds to the assigned departure runway. The heading check must be used in conjunction with external cues to confirm the correct runway." This procedure was added to the company's lineup checklist.

[134] The Safety Board's postaccident survey of Part 121 operators revealed inconsistencies among those operators with rules governing or prohibiting takeoff operations from an unlighted runway at night. For example, one operator prohibited such takeoffs unless the flight crew was given permission from the company's director of operations, who evaluated the risks involved. Another operator authorized takeoffs on unlighted runways as long as the visibility was adequate and enough ambient light was available for the flight crew to identify the runway surface and maintain directional control during the takeoff roll.

recommending that "directors of safety, directors of operations, trainers, and pilots develop and implement explicit standard operating procedures to be contained in pilots' operating manuals, supported in their training, and practiced in daily operations." The FAA also stated that the SAFO would "emphasize the importance of making a final confirmation that the airplane is on the assigned runway once it has crossed the hold short line onto the runway." (SAFO 07003, "Confirming the Takeoff Runway," was issued on April 16, 2007.) The FAA further stated that it would also consider addressing this issue in Part 121 training requirements.

With regard to Safety Recommendation A-06-84, the FAA stated that it planned to issue an Information for Operators (InFO) message[135] that would reach directors of safety, directors of operations, trainers, and pilots in Parts 121, 125, 135, and 91. The InFO was expected to make two points: "no runway lights, no takeoff at night" and "no takeoff on a closed runway." The FAA stated that the InFO would also recommend that directors of safety, directors of operations, trainers, and pilots of air carriers operating under Part 121 collaborate to include these key points in their pilots' manuals and training programs and to have pilots apply the key points during flight operations. (InFO 07009, "Runway Lights Required for Night Takeoffs in Part 121, was issued on May 11, 2007.)

The Safety Board's analysis of the FAA's actions in response to Safety Recommendations A-06-83 and -84 and the Board's classifications for the recommendations are discussed in section 2.4.1.

1.18.3.2 Air Traffic Control

Safety Recommendation A-00-67

On July 6, 2000, the Safety Board issued Safety Recommendations A-00-67 and -68 to address safety issues related to runway incursions and other airport surface events. Safety Recommendations A-00-67 and -68 asked the FAA to do the following:

> Amend 14 *Code of Federal Regulations* (CFR) Section 91.129(i) to require that all runway crossings be authorized only by specific air traffic control clearance, and ensure that U.S. pilots, U.S. personnel assigned to move aircraft, and pilots operating under 14 CFR Part 129 receive adequate notification of the change. (A-00-67)
>
> Amend Federal Aviation Administration Order 7110.65, "Air Traffic Control," to require that, when aircraft need to cross multiple runways, air traffic controllers issue an explicit crossing instruction for each runway after the previous runway has been crossed. (A-00-68)

[135] On October 20, 2006, the FAA issued Order N8000.91 to establish a method of sending information to operators in a timely manner. According to the order, an InFO message contains "valuable information for operators that should help them meet administrative requirements or certain regulatory requirements with relatively low urgency or impact in safety." InFO messages are not mandatory.

In an April 11, 2006, letter to the FAA, the Safety Board stated that it met with the FAA on June 30, 2005, to discuss safety recommendations related to runway incursions. During the meeting, the FAA cited its study of 1,300 runway incursion events involving pilot deviations and controller operational errors. The FAA found that only 28 of the 1,300 events included the use of 14 CFR 91.129(i) as a causal factor. The Board expressed concern with the FAA's findings and noted that, during the first 6 months of 2005, the Board identified six cases that were relevant to Safety Recommendations A-00-67 and -68. Because the Board found six cases in a 6-month period using a more limited set of data than the FAA, the Board questioned whether the FAA considered the most appropriate data source for its study and whether the FAA might have applied criteria in the study that were too restrictive.

During the June 2005 meeting, the FAA also stated its belief that no safety problem existed when proper procedures were followed and that pilots should never cross a runway unless authorized to do so. The Safety Board's April 2006 letter expressed concern about situations in which pilots might be lost or pilots might believe that they had received permission to move to a position that was different than the one that the controller intended. Thus, because 14 CFR 91.129(i) allows pilots to cross a runway without requesting a specific clearance to do so, the regulation may not provide adequate protection against simple, individual mistakes that can have catastrophic consequences. Accordingly, the Board classified Safety Recommendations A-00-67 and -68 "Open—Unacceptable Response."

Safety Recommendations A-07-30 through -32

On April 10, 2007, the Safety Board issued Safety Recommendations A-07-30 and -31 to the FAA and A-07-32 to the National Air Traffic Controllers Association (NATCA) as a result of the Board's concern about the effects of fatigue on air traffic controllers' performance. Safety Recommendations A-07-30 and -31 asked the FAA to do the following:

> Work with the National Air Traffic Controllers Association to reduce the potential for controller fatigue by revising controller work-scheduling policies and practices to provide rest periods that are long enough for controllers to obtain sufficient restorative sleep and by modifying shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance. (A-07-30)
>
> Develop a fatigue awareness and countermeasures training program for controllers and for personnel who are involved in the scheduling of controllers for operational duty that will address the incidence of fatigue in the controller workforce, causes of fatigue, effects of fatigue on controller performance and safety, and the importance of using personal strategies to minimize fatigue. This training should be provided in a format that promotes retention, and recurrent training should be provided at regular intervals. (A-07-31)

Safety Recommendation A-07-32 asked NATCA to do the following:

> Work with the Federal Aviation Administration to reduce the potential for controller fatigue by revising controller work-scheduling policies and practices to provide rest periods that are long enough for controllers to obtain sufficient restorative sleep and by modifying shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance. (A-07-32)

On July 5, 2007, the FAA responded to Safety Recommendations A-07-30 and -31. Regarding Safety Recommendation A-07-30, the FAA stated that it had convened a working group to develop shift rotation and scheduling guidelines. According to the FAA, this working group would be chaired by an FAA quality assurance safety manager and a CAMI human factors fatigue expert, and the group would consist of members of the FAA's Air Traffic Organization operational service units and operations planning service unit. The FAA stated that NATCA would be invited to participate by providing subject matter expertise.

Regarding Safety Recommendation A-07-31, the FAA stated that it would develop and implement a fatigue awareness and countermeasures training program to be used by all Air Traffic Organization operational service units. The FAA also stated that its director of technical training would be the lead for the development and implementation of the curriculum and that CAMI fatigue experts would be providing technical support. In addition, the FAA stated that the modules being developed for initial training of TRACON, tower, and en route ATC specialists would incorporate fatigue awareness information and that initial curriculum content would be developed within 12 months.

The Safety Board's analysis of the FAA's actions in response to Safety Recommendations A-07-30 and -31 and the Board's classifications for the recommendations are discussed in section 2.2.3.3. Safety Recommendation A-07-32 is currently classified "Open—Await Response."

Safety Recommendation A-07-34

On April 10, 2007, the Safety Board issued Safety Recommendation A-07-34 to the FAA as a result of the Board's concern about issues related to controller vigilance, judgment, and safety awareness. Safety Recommendation A-07-34 asked the FAA to do the following:

> Require all air traffic controllers to complete instructor-led initial and recurrent training in resource management skills that will improve controller judgment, vigilance, and safety awareness.

On July 13, 2007, the FAA stated that it had delivered CRM workshops, posters, and follow-up support to the Phoenix, Chicago, Boston, and Los Angeles ATCTs and the Las Vegas, Philadelphia, and Miami ATCTs and TRACONs. The FAA also stated that the CRM implementation plan for fiscal years 2007 through 2009 included instructor-led

training at "a percentage of" the highest-error-rate terminal and en route facilities and CRM training for initial hires in the FAA Academy and college training initiative programs. The FAA further stated that it would develop plans to train additional controllers on an initial and a recurrent basis.

The Safety Board's analysis of the FAA's actions in response to Safety Recommendation A-07-34 and classification for the recommendation are discussed in section 2.2.3.2.

1.18.4 Related Accident and Incidents

In addition to the 1989 Eastern Airlines flight 536 and American Airlines flight 508 incidents at HOU and the 1983 Korean Air Lines flight 84/South Central Air flight 59 accident in Anchorage (see section 1.18.3.1), the Safety Board has identified the following related accident and incidents:

Singapore Airlines Flight 006 Accident

On October 31, 2000, Singapore Airlines flight 006, a Boeing 747, crashed during an attempted takeoff from a partially closed runway at Chiang Kai-Shek International Airport, Taoyuan, Taiwan.[136] Of the 179 occupants aboard the airplane, 83 were killed. The report by Taiwan's Aviation Safety Council found that the pilots did not adequately review the taxi route to ensure that they understood that the route to runway 5L (the correct departure runway) required passing runway 5R (a parallel runway that was under construction and open only for taxi operations). The report also stated that the pilots did not verify the airplane's position with the taxi route as they were turning onto the runway and that the company's operations manual did not include a procedure to confirm an airplane's position on the active runway before initiating takeoff. The report concluded that the flight crew lost situational awareness and took off from the wrong runway despite numerous available cues that provided information about the airplane's position on the airport.[137] The Aviation Safety Council recommended that Singapore Airlines "include in all company pre-takeoff checklists an item formally requiring positive visual identification and confirmation of the correct takeoff runway."

China Airlines Flight 011 Incident

On January 25, 2002, China Airlines flight 011, an Airbus A340, departed from a taxiway at Ted Stevens Anchorage International Airport, Anchorage, Alaska, instead of the assigned runway. The available distance on the taxiway was 6,800 feet, but the airplane's calculated takeoff distance was 7,746 feet. The airplane took off, but its main landing gear left impressions in a snow berm at the end of the taxiway. The airplane proceeded to

[136] In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the Safety Board participated in the investigation of this accident as a representative of the State of Manufacture.

[137] Aviation Safety Council, *Crashed on a Partially Closed Runway During Takeoff, Singapore Airlines Flight 006, Boeing 747-400, 9V-SPK, CKS Airport, Taoyuan, Taiwan, October 31, 2000*, Aircraft Accident Report (Taiwan, Republic of China: Aviation Safety Council, 2002).

its destination and landed without further incident. The Safety Board determined that the probable cause of this incident was the captain's selection of a taxiway instead of a runway for takeoff and the flight crew's inadequate coordination of the departure, which resulted in a departure from a taxiway. The Board determined that a contributing factor to the incident was the lack of an operator requirement for the flight crew to verbalize and verify the runway in use before takeoff.[138] As a result of this incident, China Airlines modified its Airbus A340 operating manual to include verbalization and verification of the runway in use.

Alaska Airlines Flight 61 Incident

On October 30, 2006, Alaska Airlines flight 61, a Boeing 737, took off from runway 34R instead of runway 34C (center), which was the assigned runway, at Seattle-Tacoma International Airport (SEA), Seattle, Washington. The airplane continued uneventfully to its destination of Juneau International Airport, Juneau, Alaska.[139]

According to the captain of the flight, the ATIS that was current at the time indicated that departing aircraft were taking off either with the full length of runway 34R or at the point where the runway intersected taxiway Q. The first officer of the flight stated that the takeoff briefing included a departure from runway 34R.

The captain stated that the controller instructed the flight crew to follow a Boeing 757 to runway 34R and that the 757 departed from runway 34R where the runway intersected taxiway Q. The captain also stated that the controller instructed the crew to taxi the airplane into position and hold on runway 34C. Further, even though he repeated this information to the controller, the captain was still thinking that the airplane would be taking off from runway 34R. During this time, the first officer was completing flight paperwork and conducting other preflight activities.

After receiving takeoff clearance from runway 34C from the controller, the captain stated that he lined up the airplane on runway 34R and transferred control of the airplane to the first officer. The airplane departed uneventfully from runway 34R.

According to the controller, he was scanning the runways and noticed that the airplane was rolling on runway 34R abeam the tower instead of runway 34C. Because there were no potential air traffic conflicts at the time, the controller thought that it would be safer to let the airplane depart from runway 34R than to have the pilots abort the takeoff. After the airplane had taken off, the controller informed the flight crew that the airplane had departed from the wrong runway.

[138] More information about this accident, ANC02IA011, is available at the Safety Board's Web site at <http://www.ntsb.gov>.

[139] More information about this accident, DCA07IA008, is available at the Safety Board's Web site at <http://www.ntsb.gov>.

United Airlines Flight 1404 Incident

On April 18, 2007, about 0625, United Airlines flight 1404, an Airbus A320, taxied onto a closed runway at Miami International Airport (MIA), Miami, Florida, and began its takeoff roll. Night VMC prevailed at the time. A NOTAM indicated that runway 9/27 was closed from 2300 on April 17 to 1000 on April 18; the NOTAM was included in the flight release paperwork. The runway closure was also included in the ATIS information broadcast.

The flight crewmembers reported that they had the airport charts out and available. The controller told the flight crew to taxi the airplane to runway 30. The captain stated that he observed taxiway S almost directly opposite from the airplane's position and chose to make a left turn from taxiway S onto taxiway Q. This parallel taxi route placed the airplane adjacent to runway 30, the assigned runway for takeoff. The captain stated that, as the airplane passed the intersection with taxiway T, he verified that the runway sign was for runway 30. The first officer stated that, during this time, he was busy with flight paperwork and was accomplishing flight control checks.

Taxiway Q made a slight bend to the left after the intersection with taxiway T so that the taxiway was parallel with runway 27. The captain stated that he saw a runway, which he believed to be runway 30, when he looked to the right.

The first officer called the tower and advised that the airplane was ready to depart on runway 30. The controller cleared the airplane for takeoff from runway 30 while the airplane was still on taxiway Q. The first officer acknowledged the clearance for takeoff but did not state the runway number for the departure. The captain stated that, as the airplane neared the end of taxiway Q, he observed the hold short line and that, because the airplane was cleared for takeoff, he chose to turn directly onto the runway without stopping and transfer control of the airplane to the first officer. The first officer stated that his heading display was rotating to the right and in the correct direction to line up with the runway, which was still located to the right.

The first officer stated that he advanced the throttles, and, just before they reached the cruise thrust position, the airplane's nose wheel light illuminated a truck flashing its lights on the right side of the runway. The captain and the first officer stated that they observed the truck at the same time. Simultaneously, the controller was querying the flight crew to determine whether the airplane was on runway 30. The first officer rejected the takeoff, and the captain assumed control of the airplane.

Ramp personnel called the tower to advise that an airplane was on a closed runway, and the controller acknowledged this information. The controller subsequently advised the crew to use caution for workers and equipment on runway 27 and instructed the flight crew to taxi the airplane to runway 30. The airplane then took off to its destination airport—Dulles International Airport, Chantilly, Virginia—without further incident.

The pilots reported that the runway 27 edge lights were on. However, an airport engineer who witnessed the incident stated that he immediately scanned runway 27 after the event and noted that the runway edge lights were off.

1.18.5 Aviation Safety Reporting System Reports

The National Aeronautics and Space Administration's aviation safety reporting system (ASRS) showed 114 reports of incidents from March 1988 to September 2005 in which flight crews of turbojet airplanes lined up on the wrong runway for takeoff. The ASRS reports indicated that wrong runway takeoff events involved both intersecting and parallel runways. The ASRS reports also indicated that the pilots involved in these events, pilots of other aircraft in the area at the time, or air traffic controllers detected the mistake either before or after takeoff.

An ASRS report submitted in 1993 by an air carrier pilot operating out of LEX stated that the flight had been cleared for an immediate takeoff on runway 22 but that, because of the weather, the flight crewmembers told the controller that they "needed a moment to check departure routing with weather radar." The report further stated that the flight crew realized that the airplane's heading was not correct for the assigned runway and that "at that moment [the] tower called … to cancel takeoff clearance because [the airplane was] lined up on runway 26." The pilot who submitted the report cited poor visibility and rain as factors in this event along with a "confusing" runway intersection in which multiple runway ends were in the same general location.

1.18.6 Local Notices to Airmen Information

FAA Order 8400.10, "Aviation Safety Inspectors Handbook," volume 3, chapter 6, states the following in paragraph 1151, "Flight Information":

> NOTAM (L) or local information includes such information as airport and taxiway construction and certain airport lighting. This information is directly relevant to surface movement guidance and control. NOTAM (L)s can also contain information that is expected to be in effect for less than 1 hour concerning NAVAIDS [navigational aids], lighting, and runways. NOTAM (L)s are not normally transmitted beyond the area of coverage for the local FSS [flight service station] or automated flight service station.[140]

LEX sends local NOTAMs via fax to its airport tenants. At Comair, the local NOTAMs are received by the System Operations Control Center at company headquarters. The local NOTAMs are then taken to the System Operations Control Center's performance analyst, who reviews the local NOTAM. If the analyst determines

[140] The other NOTAM categories are distant NOTAMs, which include information such as navigational aids, landing areas, and airport lighting facilities, and flight data center NOTAMs, which are regulatory in nature. All distant and flight data center NOTAMs are disseminated globally by the FAA and are included in flight dispatch paperwork.

that the information might have an impact on a flight's schedule, then the analyst forwards the local NOTAM to Comair's planning performance group, which might make an adjustment to the schedule. If the analyst determines that the information in the local NOTAM might have an operational impact on the flight, then the analyst sends the information to the flight standards department for review. The department might decide to issue the local NOTAM as a company NOTAM. All company NOTAMs are included in the flight planning system and the flight dispatch paperwork.

In a July 2007 meeting, the FAA told the Safety Board that it was planning to align the U.S. NOTAM system with that of the International Civil Aviation Organization (ICAO)[141] in October 2007, at which time local NOTAMs would be converted to distant NOTAMs (because ICAO does not have local NOTAMs). According to the FAA, aligning with ICAO's standard NOTAM procedures will help U.S. NOTAM information be processed in a more timely, accurate, complete, and traceable manner. The FAA indicated that training on new NOTAM policies and procedures would begin in August 2007. Also, the FAA has other planned actions to modernize the current NOTAM system; these actions include having digital NOTAM data displayed in the cockpit in textual and graphical formats.[142]

1.18.7 Enhanced Taxiway Centerline Markings and Surface Painted Holding Position Signs

In 2002, the FAA's Office of Runway Safety and Operation Services sponsored a study to determine whether it was feasible to use paint markings to improve the situational awareness of pilots taxiing on the airfield. The study, which was undertaken by the Mitre Corporation, comprised an aviation industry team and a human factors team.

A January 2005 Mitre Corporation report found that enhanced taxiway centerline markings (that is, parallel yellow dashed lines on a black background that appear on either side of a taxiway centerline for 150 feet before a runway holding position marking) provided "beneficial redundancy" to pilots and increased awareness that the pilots were entering the runway environment.[143] The report also found that surface painted holding position signs (that is, white runway numbers on a red background that appear just before a runway holding position marking) were effective in increasing runway awareness among transport-category pilots. In spring 2005, authors of this report stated the following:[144]

[141] The ICAO Council, among other things, adopts standards and recommended practices concerning air navigation.

[142] This information was discussed at the FAA's May 2007 "NOTAM Industry Day" briefing.

[143] Cheryl R. Andrews, Steven L. Estes, Dr. Peter M. Moertl, and B. Oscar Olmos, *Summary of Airport Surface Marking Project*, Product No. 05W0000005, McLean, Virginia: Mitre Corporation, 2005.

[144] Steven Estes, Oscar Olmos, Cheryl Andrews, Anthony D. Andre, Susan Chrysler, and Dan Hannon, "Better Taxiway Surface Markings: Safer Airports," *Ergonomics in Design*, Spring 2005.

> Surface painted holding position signs meet several design goals. The orientation of the text supports directional information … they are also easy to understand because they mirror existing vertical signage and airport marking standards … they are easier to find because they are collocated with the hold line.

Figure 5 shows an example of enhanced taxiway centerline markings and surface painted holding position signs. Enhanced taxiway centerline markings are not currently required, but, by June 30, 2008, all Part 139 airports with 1.5 million or more annual passenger enplanements will be required to have these markings before each runway holding position. Surface painted holding position signs are currently required only where the width of the holding position on the taxiway is greater than 200 feet.

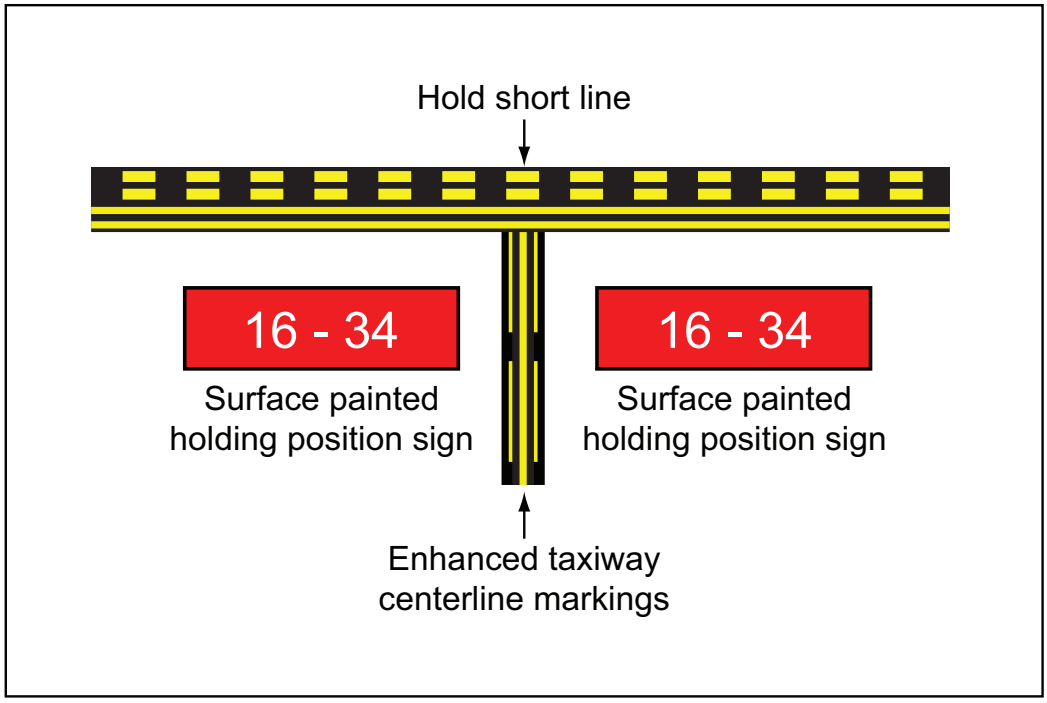


Figure 5. Enhanced Taxiway Centerline Markings and Surface Painted Holding Position Signs

1.18.8 Department of Transportation Inspector General Report

The Department of Transportation Inspector General's (DOT/IG) office issued a report, dated March 16, 2007, that presented the results of the office's review of staffing at combined radar approach control and tower with radar facilities.[145] The report stated that the FAA's vice president of terminal services issued verbal guidance in August 2005 indicating that two controllers should normally be on duty at those facilities that have

[145] U.S. Department of Transportation, *Review of Staffing at FAA's Combined Radar Approach Control and Tower With Radar Facilities*, Report Number AV-2007-038 (Washington, DC: DOT, 2007).

radar and tower functions. The report also stated that the vice president expected his area directors to disseminate this guidance to their hub managers who, in turn, would disseminate the guidance to facility managers. The DOT/IG found that, because the guidance was verbal, it was misinterpreted and inconsistently applied.

The DOT/IG reviewed a statistical sample of 20 randomly selected weeks of staffing data (between August 28, 2005, and September 2, 2006) for the midnight shift at 15 of 62 facilities (a total of 2,100 shifts). The review identified 234 midnight shifts during which only one controller was scheduled. On the basis of this finding, the DOT/IG statistically projected (with a 95-percent confidence level) that about 2,563, or 11.1 percent of the 23,002 total midnight shifts at the 62 facilities were staffed with one controller between August 28, 2005, and September 2, 2006. The report noted that the number of noncompliant facilities was higher at the beginning of the sample period than toward the end.

The DOT/IG also found evidence suggesting that, even when two controllers were on duty during the midnight shift, the radar and tower duties were combined for substantial periods instead of being staffed separately. The report stated that position logs at several facilities showed that the two controllers on duty alternated between working the combined position and taking breaks.

In addition, the DOT/IG found that, before the Comair accident, the FAA had no controls in place to ensure that facilities had consistently implemented the verbal staffing policy guidance and were uniformly complying with it. The report noted that, after the accident, the FAA formalized the verbal guidance into Notice N JO 7210.639.

The DOT/IG recommended that the FAA communicate in writing all future guidance changing or reiterating existing air traffic policies and procedures to ensure uniform implementation and compliance. The DOT/IG also recommended that the FAA develop and implement appropriate policies and procedures to ensure that facilities are complying with the provisions of FAA Notice N JO 7210.639.

2. ANALYSIS

2.1 General

The captain and the first officer were properly certificated and qualified under Federal regulations. There was no evidence of any medical or behavioral conditions that might have adversely affected their performance during the accident flight. Before reporting for the accident flight, the flight crewmembers had rest periods that were longer than those required by Federal regulations and company policy.

The accident airplane was properly certified, equipped, and maintained in accordance with Federal regulations. The recovered components showed no evidence of any structural, engine, or system failures.

Weather was not a factor in this accident. No restrictions to visibility occurred during the airplane's taxi to the runway and the attempted takeoff. The taxi and the attempted takeoff occurred about 1 hour before sunrise during night VMC and with no illumination from the moon.

This analysis discusses the taxi and attempted takeoff sequence and the associated human factor issues, survival factors, efforts to mitigate surface navigation errors, ATC staffing, and other issues related to the accident flight.

2.2 Taxi and Attempted Takeoff Sequence

The pilots attempted to take off from a different runway than the airplane had been cleared to use. Section 2.2.1 details the events leading to the attempted takeoff, section 2.2.2 considers the pilot human factors that might have played a role in this surface navigation error, and section 2.2.3 explains the ATC human factors that might have played a role.

2.2.1 Wrong Runway Departure

2.2.1.1 Before Taxi Activities

The Comair Operations Manual indicated that the captain was to conduct the taxi briefing. The briefing was to incorporate Comair standard taxi information, including that both flight crewmembers should have the appropriate airport diagrams out and available and that traversing runways required extra diligence. Comair standard taxi information was to be briefed in its entirety for the first flight as a crew and could be abbreviated to "Comair standard" for subsequent flights. The accident flight was the pilots' first flight

as a crew, but, about 0556:14, the captain stated "Comair standard" instead of all of the information in that portion of the taxi briefing, including that runway 26 was to be crossed while navigating to runway 22. The abbreviated briefing was contrary to company policy, and the Safety Board notes that it is prudent for pilots to fully conduct taxi briefings according to standard operating procedures. However, despite this abbreviated briefing (which occurred about 10 minutes before the accident), multiple and more salient cues existed to aid the flight crew while navigating to the runway, and the airport navigation task was relatively simple,[146] as discussed in this analysis.

The first officer was the flying pilot for the accident flight. About 0557:23, he briefed the taxi route as part of the takeoff briefing,[147] stating, "let's take it out and … take … [taxiway] Alpha. Two two's a short taxi." Although the CVR did not record either pilot explicitly referencing the airport chart, this statement is consistent with the first officer examining the chart because no specific taxi instructions had been provided to the flight crew. Also, the number of times that each crewmember had previously arrived at or departed from LEX was likely not sufficient to allow either one to have memorized taxiway identifiers and routes.

During the takeoff briefing, the first officer stated that the runway end identifier lights were out and then commented, "came in the other night it was like … lights are out all over the place." The first officer was referring to observations he made on a repositioning flight that landed on runway 22 about 0140 on the day before the accident. (The right runway edge lights after the intersection of runway 22 with runway 26 were out at that time.)

The first officer did not brief that the taxi to runway 22 required crossing runway 26. The Safety Board was unable to determine why this information was not included in the first officer's briefing. It is possible that the simplicity of the taxi and the use of only one taxiway might have led him to assume that it was unnecessary to include this additional information in his briefing. During postaccident interviews, other pilots indicated that they would brief this "short taxi"[148] in a similar manner. No evidence indicated that the pilots were unaware of the need to cross runway 26 to arrive at runway 22.

About 0602:01, the first officer notified the controller that the airplane was ready to taxi. The controller then instructed the flight crew to taxi the airplane to runway 22. Title 14 CFR 91.129(i), "Takeoff, Landing, Taxi Clearance," permits pilots instructed to taxi to a point on the airport surface to cross all intersecting runways along the taxi route (without stopping) except for the assigned departure runway.[149] Thus, the controller's clearance for the airplane to taxi to runway 22 complied with 14 CFR 91.129(i), and the first officer's response of "taxi two two" was an appropriate acknowledgment of the taxi

[146] Comair's high threat taxi procedures are used at those airports with an operating environment that presented "exceptional" hazards to safe taxi. However, these procedures were not in place for operations at LEX at the time of the accident.

[147] As stated in section 1.1, the takeoff briefing is part of the before starting engines checklist.

[148] Taxiway A is used for the taxi to both runways 4 and 22, but the taxi to runway 22 is significantly shorter than the taxi to runway 4, as shown on airport charts (see appendix C).

[149] This regulation is discussed further in section 2.4.4.

instruction. Because two airplanes, SkyWest flight 6819 and American Eagle flight 882, were given the same taxi clearance and had already correctly taxied to and held short of runway 22 without any special instructions, there was no apparent reason for the controller to have suspected that the pilots would have had difficulty navigating to the departure runway.[150]

2.2.1.2 Taxi to Runway

From about 0603:16 to 0603:56, while the captain was taxiing the airplane and performing navigational checking activities, both pilots resumed the nonpertinent discussion that was started while the airplane was parked at the gate. (Figure 1 shows the location of the airplane along the taxi route while this conversation was occurring.) The nonpertinent conversation was not in compliance with the sterile cockpit rule required by company procedures and 14 CFR 121.542 (see section 1.17.1.3). The primary reason for the sterile cockpit rule is to ensure that the pilots' attention is directed to operational concerns during critical phases of flight (including taxi) and is not redirected or degraded because of nonessential activities or discussion.

FDR data showed that, about 0604:33, the airplane stopped on taxiway A at the hold short line for runway 26, which was about 560 feet from the intended destination—the hold short line for runway 22. During this time, the first officer was completing the before takeoff checklist. About 0605:15, the first officer advised the controller that the airplane was ready to depart, and the controller told the flight crew that the airplane should fly the runway heading and was cleared for takeoff. Neither the first officer nor the controller stated the runway number during the request and clearance for takeoff, but ATC procedures did not require them to do so. Because the flight crew believed that the airplane was at the hold short line for runway 22 at the time of the takeoff clearance (see section 2.2.2.3), the absence of a reference to runway 22 in the request and clearance for takeoff was not a factor in this accident.

The 50-second timeframe during which the airplane was stopped at the runway 26 hold short line should have provided the flight crew with ample time to look outside the cockpit and determine the airplane's position on the airport. At this position, the flight crew would have been able to see the runway 26 holding position sign, the "26" painted runway number, the taxiway A lights across runway 26, and the runway 22 holding position sign in the distance.[151]

FDR data showed that, about 0605:24, the captain began to taxi the airplane across the runway 26 hold short line. FDR data also showed that, about 0605:41, the airplane began to turn onto runway 26, and the CVR showed that, about 0605:46, the first officer completed the lineup checklist.

---

[150] In accordance with FAA Order 7110.65, "Air Traffic Control," paragraph 3-7-2, the controller would have been required to provide turn-by-turn directions to the departure runway if the flight crew had so requested.

[151] During the 50-second timeframe, the controller did not query the flight crew regarding why the airplane was stopped at the hold short line for runway 26. The controller's actions during the taxi and attempted takeoff sequence are discussed in section 2.2.3.

2.2.1.3 Takeoff Roll

About 0605:58, the captain transferred control of the airplane to the first officer, stating, "all yours," to which the first officer acknowledged, "my brakes, my controls." At this time, the captain would have switched his attention from outside to inside the cockpit, and the first officer would have switched his attention from inside to outside the cockpit. About 2 seconds later, the airplane was aligned with the centerline for runway 26.

The CVR recording showed that the flight crew had referred to runway 22 as the departure runway multiple times before takeoff, and FDR data showed that the pilots' heading bugs were set to 227°, which was consistent with the magnetic heading for runway 22. The Safety Board concludes that the captain and the first officer believed that the airplane was on runway 22 when they taxied onto runway 26 and initiated the takeoff roll.

About 0606:16, the first officer stated, "[that] is weird with no lights," to which the captain responded, "yeah." At that time, the airplane was passing through the intersection of runway 26 with runway 22. About 0606:24, the captain called the 100-knot airspeed check. About the same time, the airplane accelerated beyond the maximum airspeed that would have allowed the airplane to remain on the available runway if the flight crew had rejected the takeoff and used maximum braking.[152]

At 0606:31.2, the captain called, "V one, rotate," followed immediately by his exclamation, "whoa." The aircraft performance study for this accident showed that, at the time of the V_R callout, the airplane was 236 feet from the end of the runway. The appearance of the runway end environment would have provided a salient cue to the flight crew that the airplane was in an extremely hazardous situation and could not remain on the ground. The airplane's airspeed at the time of the captain's V_R callout was 131 knots, which was 11 knots below the planned V_R airspeed of 142 knots (which the flight crew had briefed and entered into the airplane's EFIS).[153] Thus, the captain's early V_R callout and subsequent "whoa" exclamation indicated that he recognized that something was wrong with the takeoff.

FDR data showed that, in response, the first officer pulled the control column full aft[154] and that the airplane rotated at a rate of about 10° per second, which is three times the normal rotation rate. This abnormal column input showed that the first officer also recognized that something was wrong with the takeoff.

Although numerous cues, including the lack of runway lighting, were available to indicate that the airplane was not on the assigned runway (see sections 2.2.2.1 and 2.2.2.3),

[152] According to calculations by Bombardier, for the airplane to have stopped before the end of runway 26, maximum braking would have had to start when the airplane was at an airspeed of about 103 knots.

[153] FDR data for the accident airplane's 12 previous takeoffs indicated that rotation occurred at or after reaching the V_R airspeed.

[154] FDR data showed that the left and right control column inputs during the accident rotation reached 10.6° and 10.9°, respectively, and that the nominal control column input for rotation during the accident airplane's 12 previous takeoffs was between 4° and 5°.

the flight crew had not correctly interpreted these cues or noticed them until after it was too late to successfully abort the takeoff. The Safety Board concludes that the flight crew recognized that something was wrong with the takeoff beyond the point from which the airplane could be stopped on the remaining available runway.

2.2.1.4 Runway Incursions

The FAA currently defines a runway incursion as "any occurrence in the airport runway environment involving an aircraft, vehicle, person, or object on the ground that creates a collision hazard or results in a loss of required separation with an aircraft taking off, intending to take off, landing, or intending to land." ICAO defines a runway incursion as "any occurrence at an aerodrome involving the incorrect presence of an aircraft vehicle or person on the protected area of a surface designated for the landing and take-off of aircraft." According to these definitions, ICAO would classify this accident as a runway incursion, but the FAA would not consider this accident to be a runway incursion because no other airplane impeded the accident airplane's ability to take off. The Safety Board notes that the presence of another airplane on a runway should not be a consideration in determining whether a runway incursion has occurred; rather, criteria for making this determination should consider, among other things, whether an airplane's movement is consistent with the clearances provided to the flight crew. As a result, the Safety Board concludes that, because the accident airplane had taxied onto and taken off from runway 26 without a clearance to do so, this accident was a runway incursion.[155]

At the Safety Board's runway incursion forum in March 2007, the FAA announced that it planned to revise its definition of a runway incursion to align with ICAO's definition by the end of fiscal year 2007 and that it would begin reporting runway incursions according to the revised definition in fiscal year 2008. The Board is encouraged by the FAA's plan to adopt and apply the ICAO definition because wrong runway takeoffs should be reflected in runway incursion statistics so that runway safety trends can be accurately monitored and appropriate countermeasures can be taken.

2.2.2 Pilot Human Factors

The flight crew's performance on the day of the accident seemed to be uncharacteristic with past reports. The captain and the first officer were described favorably by company personnel, and pilots who had flown with them described both as competent pilots who had not previously demonstrated difficulty with airport surface operations. The captain was described as someone who managed the cockpit well, adhered to standard operating procedures, and demonstrated good CRM. The first officer was preparing for an opportunity to upgrade to captain and was described as someone who would have made a good captain because of his adherence to standard operating procedures.

[155] Even though the FAA does not consider the SEA and MIA incidents (discussed in section 1.18.4) to be runway incursions, the Safety Board does consider these incidents to be runway incursions.

The Safety Board examined possible reasons why the flight crew stopped at the incorrect hold short line and attempted to take off from the incorrect runway, as discussed in sections 2.2.2.1 through 2.2.2.4.

2.2.2.1 Available Cues and Aids for Wayfinding

Pilots integrate many sources of wayfinding information, either alone or in combination, to establish their position and navigate to their intended destination on the airport. Wayfinding information sources include geographic knowledge of standard airport surface features that are common to all airports (such as terminal buildings, ramp areas, taxiways, and runways), knowledge of standard conventions for marking and identifying airport surface features, airport charts, and taxi instructions from ATC.

Because both pilots were experienced, they should have been knowledgeable about basic airport geographic features and signage and surface marking standards (the Safety Board did not note any signage or surface markings at LEX that were not in compliance with FAA regulations), and they should have been skilled at interpreting airport charts. In addition to their knowledge about the specific route (taxiway A to runway 22), multiple external cues and features were available to the pilots to support their navigation to runway 22, and no evidence indicated that their view from the windscreen was obstructed. Observations from a CRJ-100 airplane after the accident demonstrated that, during nighttime conditions, taxiway location signs were visible along the full length of the taxi route, a runway 26 holding position sign adjacent to the runway 26 hold short line was visible, and the runway 26 numbers were visible. Also, evidence indicated that, at the time of the accident, the signs identifying the critical features along the taxi route (that is, the runway 26 holding position sign, the taxiway A extension across runway 26, and the runway 22 holding position sign) were illuminated and would have been visible to both pilots.[156]

The flight crewmembers had resources available to them within the cockpit to support their navigation to runway 22, including the Jeppesen airport chart. Even though discrepancies existed between the airport chart and the external cues available to the pilots because of an ongoing construction project at the airport,[157] the chart depicted the paved taxiway and runway surfaces at the time of the accident.

Another available resource within the cockpit was the instrumentation, including the heading bug, which had been set to 227° to correspond to the magnetic heading for runway 22. This heading information, which was clearly presented on both flight crewmembers' MFDs and PFDs, would have provided the pilots with a real-time cue of their orientation relative to runway 22.

[156] Although the first officer's attention was focused inside the cockpit while the airplane was taxiing to the departure runway, he would have had multiple opportunities to look outside the cockpit and monitor the airplane's progress along the taxi route. Such monitoring would have helped the first officer gauge and pace his activities with the available time left for taxi.

[157] Taxiway A north of runway 26 had been closed (as indicated by a local NOTAM) and barricaded, and taxiway A5 had been redesignated as taxiway A. Neither of these changes was depicted on the airport chart. However, no evidence indicated that either pilot was confused by the discrepancies. In addition, the pilots of SkyWest flight 6819 and American Eagle flight 882 used the same chart to navigate to runway 22.

In addition, the flight crewmembers could have communicated with the controller if they became unsure of their position at any time.[158] However, the CVR did not record any statement by either flight crewmember about being unsure of the airplane's position on the airport surface at any time during the taxi and takeoff roll. The CVR also did not record any indication that the crewmembers had attempted to confirm the airplane's position on the runway before beginning the takeoff roll.

The taxi routing and cues available to the accident pilots were identical to those that were available to the pilots of the two regional jets (SkyWest flight 6819 and American Eagle flight 882) that departed before Comair flight 5191. The SkyWest and American Eagle pilots had no difficulty identifying, and successfully navigating to, runway 22 using the available cues,[159] even with the differences in taxiway signage and chart labeling.[160] In addition, even though the airport configuration at the time of the accident had been in place for 1 week, the Safety Board did not identify any reports about surface navigation problems at LEX during that time.[161] The Safety Board concludes that adequate cues existed on the airport surface and available resources were present in the cockpit to allow the flight crew to successfully navigate from the air carrier ramp to the runway 22 threshold.

2.2.2.2 Preflight Activities and Actions During the Taxi

Because the availability of cues and aids for the pilots' wayfinding task was not a factor in this accident, the Safety Board examined the crew's actions during the preflight and taxi phases of the flight's operation to identify possible reasons for the error.

The flight crew proceeded from the Comair operations center to the air carrier ramp area, where two Comair CRJ airplanes were located. The crew initially boarded the wrong airplane,[162] even though the tail number of the airplane to be used for the flight

[158] Such communications would have been consistent with good CRM (while at towered airports) and company policy. In addition, this behavior would have been consistent with reports of the pilots' past performance.

[159] The SkyWest first officer stated that he became "momentarily confused" about the airplane's orientation when he looked up while crossing runway 26 but that he was able to reorient himself after identifying the holding position sign for runway 22.

[160] The SkyWest and American Eagle pilots did not recall seeing the low-profile barriers on taxiway A north of runway 26. The pilots' lack of recall in this area indicates that the barriers were not significant elements in the pilots' wayfinding and that the taxiway A closure did not encumber their navigation to runway 22. The pilots' lack of recall does not indicate that the barriers were inconspicuous or difficult to see when approaching or crossing runway 26. In fact, observations in a CRJ-100 airplane after the accident indicated that the barriers would have been clearly visible to the pilots during the taxi. The pilots' failure to recall these barriers is not unusual because people can have difficulty remembering things in their environment with which they did not interact.

[161] After runway 26 was reopened (November 2006), two events occurred in which air traffic controllers informed pilots that their airplanes were on that runway instead of runway 22 (see section 1.10.4). However, an interview with the pilot involved in the first event indicated that he had stopped for preflight activities, was aware of the airplane's position, and did not intend to depart on runway 26. An interview with the captain of the flight involved in the second event indicated that he became temporarily confused about the location of runway 22 but that the airplane was never lined up to take off from runway 26. An interview with the first officer of this flight indicated that he and the captain were never confused about the correct runway for takeoff.

[162] The Safety Board does not know which pilot was the first one to board the wrong airplane.

was included in the flight release paperwork, and started its APU. Although these actions likely consumed a portion of the crew's available time at the gate, CVR evidence and interviews with ground personnel indicated that neither pilot appeared to be rushed or hurried as he completed required tasks. For example, as stated in section 2.2.1.2, the CVR recorded both crewmembers involved in a detailed nonpertinent discussion before and during pushback from the gate, which indicated that both crewmembers were relaxed. In addition, FDR data showed that the navigation to the runway was conducted at a normal pace, and the controller stated that the pilots did not seem to be rushed. Thus, the available evidence indicated that the flight crew was not under time pressure.

The Safety Board reviewed the CVR recording to evaluate the flight crew's workload and focus of attention during the taxi to the runway. While the captain was maneuvering the airplane along the taxi route, the first officer was performing preflight checklists, including some additional items that were necessary because the flight was the airplane's first flight of the day. Although FDR data showed that the taxi lasted only about 2 1/2 minutes, the first officer had adequate time to complete the preflight activities. It is important to note that the first officer was experienced in his position and that these activities, including the first-flight-of-the-day items, would have been well learned and would not have presented him with a high workload condition.

In addition to navigating the airplane along its taxi route, the captain would have been overseeing the first officer's performance and providing cross-checking as necessary. The captain was also experienced in his position and would have been skilled at dividing his attention between controlling the airplane, navigating the airport, and monitoring the first officer's performance. Moreover, with the captain's level of experience, the control inputs associated with controlling an airplane on an airport surface would have required very little cognitive effort.

The nonpertinent conversation occurred during 40 seconds of the 150-second taxi time (from about 0603:16 to about 0603:56). The timing of this discussion and its duration are the most salient evidence to demonstrate that neither pilot was experiencing high workload at the time or considered the taxi to runway 22 to be a challenging task. However, people have limited attention resources, and, when distracted by conversation, both real-time processing of information and prospective memory (that is, remembering to do something at a later time) can suffer.[163]

More than 20 years of research using the ASRS database has shown that pilots cite social conversation with other crewmembers as an activity that can distract the pilots from tasks that must be performed.[164] Also, human factors research on aviation wayfinding indicated that any breakdown in a pilot's assessment of position "can result

[163] R.K. Dismukes, "Concurrent Task Management and Prospective Memory: Pilot Error as a Model for the Vulnerability of Experts." *Proceedings of the Human Factors and Ergonomics Society 50th Annual Meeting*, 2006.

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

in either a slight deviation from an intended path, or becoming totally lost."[165] In addition, active attention is thought to be necessary for maintaining situational awareness, and the allocation of attention to irrelevant stimuli can degrade awareness.[166] Finally, research on distractions while driving found that drivers are less likely to detect changes that have occurred in the environment when they are involved in casual conversation because being engaged in a conversation may degrade the encoding of visual information.[167]

The first officer initiated the nonpertinent conversation as the captain was navigating along the taxi route. The captain had the responsibility to assert both his leadership role and command authority to stop the discussion. Rather, the captain allowed the conversation to continue and participated in it. Also, instead of initiating the nonpertinent conversation, the first officer should have been monitoring the captain's actions and independently assessing the airplane's location along the taxi route. The Safety Board concludes that the flight crewmembers' nonpertinent conversation during the taxi, which was not in compliance with Federal regulations and company policy, likely contributed to their loss of positional awareness. It is important to note that the CVR did not record any statement by either flight crewmember about this loss of positional awareness.

2.2.2.3 Cues to Indicate a Takeoff From Runway 22

The presence of runway markings—a white centerline and side stripes—ahead of the airplane would have facilitated the captain's perception that the airplane had arrived at the hold short line for runway 22, even though the airplane was actually at the hold short line for runway 26. In addition, the angle from the runway 26 hold short line on taxiway A to runway 26 was the same as the angle from the runway 22 hold short line on former taxiway A (north of runway 8/26) to runway 22.

Also, the taxiway A centerline split into three lines after the runway 26 hold short line. These extended taxiway centerlines led onto the closed portion of taxiway A, across runway 26 to runway 22, and onto the runway 26 centerline (a lead-on/off line). The presence of a lead-on/off line from a taxiway directly to a runway could have supported the captain's perception that the airplane had arrived at the departure runway.

In addition, as stated in section 2.2.1.1, the first officer told the captain during his takeoff briefing, "lights are out all over the place," in reference to observations he made while landing on runway 22 about 0140 on the day before the accident. The first officer's statement might have contributed to the captain's perception that the airplane was taxiing onto runway 22 because he might have anticipated a dark runway environment. At the

---

[165] R. Conejo and C.D. Wickens, *The Effects of Highlighting Validity and Feature Type on Air-to-Ground Target Acquisition Performance*, Technical Report ARL-97-11, Savoy, Illinois: University of Illinois Aviation Research Lab, 1997.

[166] C.D. Wickens and J.S. McCarley, *Attention-Situation Awareness (A-SA) Model of Pilot Error*, Technical Report ARL-01-13/NASA-01/06, Savoy, Illinois: University of Illinois Aviation Research Lab, 2001.

[167] Jason S. McCarley, Margaret J. Vais, Heather Pringle, Arthur F. Kramer, David E. Irwin, and David L. Strayer, "Conversation Disrupts Change Detection in Complex Traffic Scenes," *Human Factors*, vol. 46, no. 3, pages 424-436, 2004.

least, this statement reduced the significance of the first officer's subsequent statement, "[that] is weird with no lights" (to which the captain responded "yeah"), as the airplane rolled down runway 26.

There are well-known psychological concepts associated with perception and decision-making that can allow a person's mistaken assessment to persist. For example, confirmation bias occurs when people seek out or observe elements in their environment that support their perception. Specifically, confirmation bias results from a tendency for people to primarily seek out confirming evidence of a belief while spending less effort to seek out negative evidence that can disconfirm the belief.[168] Confirmation bias can cause a person to persist in holding an incorrect belief despite the availability of contradictory evidence. For the flight crew, confirmation bias was in place not only at the hold short line for runway 26 but also during the initial acceleration down the runway because the crew did not evaluate evidence that would contradict the airplane's position on the airport surface at the time.

There were cues available to the flight crew that were not consistent with a taxi onto runway 22. These cues included the runway holding position sign for runway 26, the 75-foot painted width of runway 26 (versus the 150-foot width of runway 22),[169] and the absence of runway edge lights and precision runway markings (such as threshold markings and touchdown zone markings) on runway 26. However, once the flight crewmembers had navigated to what they believed was the correct runway, they were likely no longer giving strong weight to contradictory information as a result of confirmation bias.

On July 17, 1989, the Safety Board issued Safety Recommendation A-89-74, which asked the FAA to ensure that the operations manuals of all Part 121 and 135 air carriers require flight crews to cross-check the heading indicator with the runway heading when the airplane is aligned with the runway for takeoff. The Board classified Safety Recommendation A-89-74 "Closed—Acceptable Action" on December 11, 1990, after the FAA revised ACOB 8-85-1 to address the need for pilots to cross-check the heading indicator with the runway heading before takeoff. These bulletins, however, are not mandatory, and, during this investigation, the Board determined that Comair and other Part 121 operators did not have procedures for positively verifying that an airplane was aligned on the correct departure runway.[170]

FDR data showed that, at some point before the start of the recording, the pilots' heading bugs had been set to 227° to correspond to the magnetic heading for runway 22.

[168] The Safety Board notes that confirmation bias has multiple definitions. This report refers to confirmation bias as a phenomenon that occurs automatically (that is, without conscious intervention or intent) at the perceptual level.

[169] Postaccident observations from a CRJ-100 airplane indicated that the reduced available width of runway 26 was clearly visible at night because the side stripes were brightly illuminated by the airplane's external lighting system.

[170] As a result of this finding and the finding that that some Part 121 operators (including Comair) did not provide guidance to their pilots about conducting takeoffs at night on unlighted runways, the Safety Board issued Safety Recommendations A-06-83 and -84 on December 12, 2006 (see sections 1.18.3.1 and 2.4.1).

At the time that the first officer began to increase thrust for takeoff, FDR data showed that the magnetic heading of the airplane was about 266°, which corresponded to the magnetic heading for runway 26. Figures 6 and 6a show the approximate configuration of the captain's MFD and PFD, including the heading bug setting and magnetic heading indication, when the airplane was lined up on the runway 26 centerline. As shown in the figures, the heading bug was offset by 40°, providing a salient cue that the airplane was not lined up on the correct departure runway. The CVR did not record any awareness by the flight crewmembers about this offset.



Figure 6. Multifunction Display

Source: Rockwell Collins. The display was configured as requested by the Safety Board.



Figure 6a. Primary Flight Display

Source: Rockwell Collins. The display was configured as requested by the Safety Board.

The wayfinding task includes an ongoing cross-check between an airplane's expected and actual position using available cues in the environment and aids in the cockpit. The CVR did not record any discussion by the flight crew about the need to cross-check the airplane's position on the runway.[171] The Safety Board concludes that the flight crewmembers failed to recognize that they were initiating a takeoff on the wrong runway because they did not cross-check and confirm the airplane's position on the runway before takeoff and they were likely influenced by confirmation bias.

[171] On March 23, 2007, Comair revised its operations manual to include a departure runway checklist item.

2.2.2.4 Fatigue

The Safety Board examined whether pilot fatigue could have been a factor in this accident by assessing the preconditions that could allow for the development of a fatigued state and examining the nature of the pilots' demonstrated performance deficiencies. Potential conditions that can lead to the development of a fatigued state include chronic sleep restriction, acute sleep loss, circadian disruption (work during times when one would normally be asleep), and time since awakening.

The captain and the first officer received more than the minimum required rest periods during their respective trips in the days before the accident, and their flight and duty times in the week and month before the accident would not have precluded them from obtaining adequate sleep. Also, both pilots had only been awake for about 2 hours at the time of the accident.[172]

Two factors in the pilots' schedules just before the accident could have been associated with the potential development of a fatigued state: acute sleep loss and circadian disruption. Evidence indicated that both flight crewmembers likely went to sleep between 2100 and 2200 on the night before the accident (as discussed later in this section) and awoke the next morning about 0415,[173] which would have afforded each pilot about 6 to 7 hours of available sleep time (which is 1 to 2 hours less than the nominal 8-hour sleep period). Restricting sleep by 2 hours has been shown to result in slight decreases in the performance of simple cognitive tasks, but there are individual differences on whether such effects are realized.[174]

The captain and the first officer also awakened on the day of the accident at a time when they would normally be asleep. The pilots' time of awakening occurred during the period known as the "circadian trough" (0300 to 0500), which is a time of decreased alertness and cognitive performance among people who are adapted to sleeping at night. However, at the time of the accident, the pilots had been awake for 2 hours, at which time circadian factors would have increased their alertness.

More importantly, from a circadian disruption standpoint, the first officer likely went to sleep about 0230 on August 26, 2006.[175] According to his wife, the first officer

---

[172] A review of the flight and duty times for the pilots of SkyWest flight 6819 and American Eagle flight 882 showed that these times were similar to those of the accident pilots.

[173] Hotel records indicated that the captain received a wake-up call at this time. The Safety Board estimated a similar wake-up time for the first officer.

[174] H.P.A. Van Dongen, G. Maislin, et al., "The Cumulative Cost of Additional Wakefulness: Dose-Response Effects on Neurobehavioral Functions and Sleep Physiology From Chronic Sleep Restriction and Total Sleep Deprivation," *Sleep*, vol. 26, no. 2, pages 117-126, 2003.

[175] Hotel key card records showed activity for the first officer's room at 2257 on August 25, 2006. After the accident, hotel personnel tested the lock on the first officer's room and determined that the actual time of key card activity was 2 hours later than shown in the records (that is, 0057 on August 26). However, the first officer's repositioning flight arrived at LEX about 0140, and the captain of the flight estimated that the first officer checked into his hotel room about 0210. As a result, the Safety Board determined that the actual time of key card activity was 3 hours later than shown in the records, indicating that the first officer arrived in his room about 0157.

was able to sleep in that morning. The Safety Board was unable to determine how many hours the first officer slept, but, if he had received 8 hours of sleep, the first officer would have awakened about 1030. With this awakening time, it could have been difficult for the first officer to fall asleep after the call to his wife (which ended at 2102) because he would have been awake for only about 11 hours. However, it is unknown whether this time since awakening would have affected the first officer's ability to obtain restful sleep on the night before the accident because it is unknown whether he actually obtained 8 hours of sleep on the morning of August 26 and whether his estimated bedtime was close to his normal sleep time.

Although there was evidence of some preconditions that were conducive to the development of fatigue in both flight crewmembers, the uncertainty associated with the pilots' actual recent sleep times made it difficult to assess the degree of fatigue that they might have been experiencing on the morning of the accident. If the captain and first officer were able to maximize their available sleep time, they might have been experiencing only mild fatigue resulting from a slightly restricted sleep period (about 7 hours) the night before the accident. In addition, any use of caffeine by the crewmembers could have served as an effective countermeasure for mild fatigue impairment.[176]

The absence, or the presence, of preconditions that are conducive to the development of fatigue is not sufficient by itself to determine whether fatigue was a factor in an accident. For fatigue to be considered a factor, performance deficiencies need to be clearly discernible and consistent with the known effects of fatigue, and any evidence supporting alternative explanations for such deficiencies needs to be considered.

In this accident, the surface navigation error and the attempted takeoff from the wrong runway were the most significant errors made by the flight crew. Other errors included the flight crew boarding the wrong airplane, the first officer asking during his takeoff briefing about the runway in use and offering up "two four," the first officer repeating some items on the before starting engines checklist after having already completed it, and the first officer misidentifying the flight as "Comair one twenty one" when informing the controller that the flight was ready to depart. In addition, the CVR recorded the first officer using a yawning voice for two consecutive statements beginning about 0603:02.

The CVR recording also indicated that the captain corrected some of the first officer's errors.[177] For example, the captain stated "its two two" when queried about the runway in use and pointed out that the before starting engines checklist had been completed. Such corrections are inconsistent with a fatigue impairment.

[176] The wives of the captain and the first officer reported that their husbands drank coffee, and the CVR recorded the captain (about 0553:04) asking the flight attendant for a cola.

[177] About 0549:49, the controller provided the flight crew with a modified clearance to ATL. The first officer told the controller that he "missed" the arrival route part of the clearance, but he acknowledged the rest of the clearance. The controller repeated the arrival information, which the first officer acknowledged. Because the arrival route information provided by the controller was different than that in the flight release paperwork, the first officer's request for the controller to repeat the arrival information cannot be considered an error but rather a request for clarification, which is a normal event.

This investigation was constrained by a lack of available information to establish the pilots' sleep activities before the accident flight. For example, the Safety Board was unable to determine how much sleep the first officer obtained on the morning of August 26, 2006, whether either pilot received supplemental sleep (in the form of naps) during the afternoon of August 26, or whether the pilots' sleep time was uninterrupted.[178] Also, the Board was unable to obtain reliable information about the nominal sleep needs for the pilots or their normal sleep and wake patterns.

It is important to note, however, that both crewmembers seemed to be aware of the need to obtain adequate rest for the next day.[179] Specifically, each pilot called his wife on the evening of August 26, 2006. The telephone call from the captain to his wife ended about 2127. The captain told his wife that he was planning on going to sleep afterward. The telephone call from the first officer to his wife ended about 2102. The first officer told his wife that he was going to bed early. Also, the Safety Board listened to a taped telephone conversation made by the first officer to the Comair System Operations Control Center at 0510 on the day of the accident; he was clear and conversational at that time. Further, witnesses reported that the pilots did not demonstrate behaviors consistent with being tired, such as yawning, stretching, and rubbing their eyes. In addition, CVR evidence showed that (1) neither pilot acted withdrawn or irritable or made any statements about receiving an inadequate amount of sleep and (2) both pilots were sociable.

The Safety Board concludes that, even though the flight crewmembers made some errors during their preflight activities and the taxi to the runway, there was insufficient evidence to determine whether fatigue affected their performance.

Previous Fatigue-Related Accidents

Even though there was insufficient evidence for the Safety Board to determine whether fatigue affected the Comair flight crew's performance, the Board has previously cited fatigue impairment as a causal or a contributing factor for those accidents in which documented performance deficiencies were consistent with the effects of fatigue and clear evidence showed that the pilots' recent activities were conducive to fatigue. For example, in its report on the June 1, 1999, American Airlines flight 1420 accident, the Board found that the flight crewmembers failed to discontinue the approach to the airport when severe thunderstorms had moved into the area and failed to ensure that the flight spoilers had extended after touchdown. The Board also found that the flight crewmembers were nearing the end of a long duty day and that, although the pilots had slept more than 9 hours the night before, they had been continuously awake for at least 16 hours by the

[178] As stated in section 1.5.2, the Safety Board was unable to determine whether the first officer attempted to answer the two consecutive incoming calls to his cell phone about 0103 on the day of the accident.

[179] The Safety Board has previously identified the need to improve fatigue awareness among pilots. Most recently, on February 7, 2006, the Safety Board issued Safety Recommendation A-06-11, which asked the FAA to "require 14 *Code of Federal Regulations* Part 121 and 135 operators to incorporate fatigue-related information similar to that being developed by the Department of Transportation Operator Fatigue Management Program into their initial and recurrent pilot training programs; such training should address the detrimental effects of fatigue and include strategies for avoiding fatigue and countering its effects." Safety Recommendation A-06-11 was classified "Open—Acceptable Response" on November 9, 2006.

time of the accident.[180] According to the report, contributing to the accident was the flight crew's "impaired performance resulting from fatigue."[181]

Also, in its report on the October 19, 2004, Corporate Airlines flight 5966 accident, the Safety Board found that the flight crew did not follow established procedures and properly conduct a nonprecision approach at night in instrument meteorological conditions and did not adhere to the established division of duties between the flying and nonflying pilot. The Board also found that the pilots' work schedule required them to go to bed and wake up much earlier than normal and that they had only a 9-hour rest period before having to report for duty. Before the accident flight, the captain told family members that he slept poorly, and other pilots saw him trying to take a brief nap in a meeting area. By the time of the accident, the flight crew had been awake for 15 hours and on duty for 14 1/2 hours and was performing the sixth flight leg of the day. According to the report, the pilots' fatigue "likely contributed to their degraded performance."[182]

In contrast to the Little Rock and Kirksville flight crews, the Comair captain and first officer had rest periods of more than 13 and 27 hours, respectively, before reporting for the accident flight. Also, the Comair pilots had only been awake for 2 hours and on duty for less than 1 hour at the time of the accident.

2.2.2.5 Cockpit Discipline

The captain was responsible for establishing the tone in the cockpit so that disciplined adherence to standard operating procedures would be maintained and crew vigilance would not be reduced. However, as recorded on the CVR, the captain told the first officer several times, "at your leisure," with regard to his performance of checklists, which was indicative of a casual cockpit atmosphere. The first officer apparently adopted this casual attitude when he told the controller that the flight was ready to depart at his leisure.

According to Comair procedures, the captain was responsible for calling for the taxi, before takeoff, and lineup checklists, but the CVR did not record the captain formally call for the before takeoff checklist. Instead, after the first officer finished the taxi checklist, the captain stated about 1 minute later, "finish it up your leisure," referring indirectly to the need to conduct the before takeoff checklist. Also, as previously stated, the captain performed an abbreviated taxi briefing, which was contrary to company guidance, and the flight crew engaged in a nonpertinent conversation while the airplane was in a critical phase of flight, which was not in compliance with the sterile cockpit regulation and

[180] Research has indicated that lapses in cognitive performance occur when the waking day is extended beyond a normal length of 14 to 16 hours. For more information, see G.P. Kruger, "Sustained Work, Fatigue, Sleep Loss, and Performance: A Review of the Issues," *Work and Stress*, vol. 3, pages 129-141, 1989.

[181] National Transportation Safety Board, *Runway Overrun During Landing, American Airlines Flight 1420, McDonnell Douglas MD-82, N215AA, Little Rock, Arkansas, June 1, 1999*, Aircraft Accident Report NTSB/AAR-01/02 (Washington, DC: NTSB, 2001).

[182] National Transportation Safety Board, *Collision with Trees and Crash Short of the Runway, Corporate Airlines Flight 5966, BAE Systems BAE-J3201, N875JX, Kirksville, Missouri, October 19, 2004*, Aircraft Accident Report NTSB/AAR-06/01 (Washington, DC: NTSB, 2006).

company procedures. The abbreviated briefing and the nonpertinent conversation were also examples of the flight crew's casual cockpit atmosphere.

The Safety Board has discussed the role of reduced cockpit discipline in other flight crew-involved air carrier accidents. For example, in its report on the August 16, 1987, Northwest Airlines flight 255 accident, the Board found that checklists (except for the before start checklist) were not being called for or accomplished according to company procedures and that, after pushback, the flight crew initiated conversations that were not related to duty requirements and diverted the crew's attention from task-related activities. Regarding the role of cockpit discipline in these errors, the report stated, "it is the captain's responsibility to structure the manner in which his crew will accomplish its duties … he must set the tone for how this information will be proffered." The report further stated that a well-defined role structure in the cockpit reduces ambiguity about each crewmember's responsibilities and when those responsibilities will be performed.[183] In addition, data from the LOSA Collaborative[184] showed that flight crewmembers who intentionally deviated from standard operating procedures were three times more likely to commit other types of errors, mismanage more errors, and find themselves in more undesired aircraft situations compared with those flight crewmembers who did not intentionally deviate from procedures.

The Safety Board concludes that the flight crew's noncompliance with standard operating procedures, including the captain's abbreviated taxi briefing and both pilots' nonpertinent conversation, most likely created an atmosphere in the cockpit that enabled the crew's errors.

2.2.2.6 Summary of Pilot Human Factors

Even with the discrepancies that existed between airport charts and signage, the navigational task that the pilots of Comair flight 5191 faced—taxi to runway 22 via taxiway A—was straightforward and inherently simple. The primary cues for this navigational task—the airport markings and signage at hold short positions—were accurate and available to the flight crew.

Flight crews are responsible for maintaining positive control of an airplane during all phases of flight, including surface operations. An essential component to positive control is knowing the position of the airplane at all times. It was the accident pilots' responsibility, once they were cleared to taxi, to safely maneuver the airplane to runway 22. Each pilot had experience and expertise to allow the successful completion of this task using only the standard airport marking conventions; that is, once the pilots detected and recognized signs off the air carrier ramp that identified taxiway A, they

[183] National Transportation Safety Board, *Northwest Airlines, Inc., McDonnell Douglas DC-9-82, N312RC, Detroit Metropolitan Wayne County Airport, Romulus, Michigan, August 16, 1987*, Aircraft Accident Report NTSB/AAR-88/05 (Washington, DC: NTSB, 1988).

[184] According to its Web site, the LOSA Collaborative is a network of researchers, safety professionals, pilots, and airline representatives collaborating to provide, among other things, oversight and implementation of LOSA and a forum for information exchange regarding LOSA. The referenced data were provided to the Safety Board in January 2007.

had only to follow those signs and the taxiway centerline to the runway holding position sign for runway 22. Although this task is more difficult during night conditions, when surrounding features in the environment and horizon as well as other cues are not easily detectable, the critical features along the navigation route were internally lit or were illuminated by the airplane's external lighting system.

Both pilots were described to be in good health in the days before the accident.[185] Postaccident toxicological testing for both pilots did not detect the presence of alcohol[186] or any substances known to affect performance.

Both pilots were required to wear corrective lenses during flight operations. Evidence indicated that the captain was wearing contact lenses during the accident flight, but the Safety Board could not determine whether the first officer was wearing corrective lenses during the flight. Even if the first officer had not been wearing corrective lenses, his ability to verify the airplane's position during the taxi to runway 22 would most likely not have been affected.[187] Evidence indicated that both pilots were able to read and interpret features inside the cockpit at intermediate distances and detect objects outside the cockpit at greater distances, and the pilots were described to have normal night vision. Observations in a CRJ-100 airplane after the accident demonstrated that no objects along the taxi route would have produced temporary flash blindness[188] that could have impeded the pilots' ability to detect signage and surface markings.[189]

As previously stated, numerous cues were available to the flight crew to indicate that the airplane was not at the position on the airport surface that it was supposed to be. For example, when the airplane stopped at the runway 26 hold short line instead of the runway 22 hold short line, the flight crew would have been able to see the runway 26 holding position sign and painted runway numbers, the continuation of taxiway A across runway 26, and the runway 22 holding position sign. Also, when the airplane was in

[185] The first officer tested positive for a low level of pseudoephedrine. This drug, at low levels, is not considered to cause impairment. Performance-based side effects of pseudoephedrine are similar to those of caffeine. CAMI does not quantify this substance unless it is above therapeutic levels. The Safety Board was not able to determine why and when the medication was taken.

[186] On August 26, 2006, at 1826, the first officer purchased food and two bottles of beer at the hotel restaurant. (Section 1.17.1.6 describes the FAA's and Comair's alcohol use policy.) According to the CAMI toxicology report, the first officer tested negative for ethanol. On the basis of known information about the first officer's height, weight, and normal alcohol consumption, it is likely that the two beers would have been metabolized within a few hours of consumption. Research has shown that low blood alcohol concentrations do not appear to be associated with significant sleep disruption or reduced feelings of well being the next morning for normal, healthy people and that a low blood alcohol concentration is unlikely to have a significant impact on performance the next day. For more information, see B. Feige, H. Gann, R. Brueck, M. Hornyak, S. Litsch, F. Hohagen, and D. Riemann, "Effects of Alcohol on Polysomnographically Recorded Sleep in Healthy Subjects," *Alcoholism: Clinical and Experimental Research*, vol. 30, pages 1527-1537, 2006.

[187] At his July 18, 2006, FAA medical examination, the first officer's uncorrected distance vision measurement was 20/30.

[188] Temporary flash blindness results when an observer adapted to darkness is exposed to a very bright light and is then returned to conditions of darkness. Such high-intensity light exposures can dramatically reduce an observer's visual acuity in low-light conditions for several minutes.

[189] No aircraft were operating near the accident airplane during taxi. The CVR contained no mention of lightning, and ground personnel interviewed after the accident did not report the presence of lightning near the airport.

position at runway 26 instead of runway 22, the crew would have been able to see the holding position sign for runway 22 and the 75-foot width of the runway (versus the 150-foot width of runway 22).

Given the numerous cues that were available to the flight crew and the simplicity of the navigation task, the Safety Board could not determine why the flight crew stopped the airplane at the incorrect hold short line and then attempted to take off from the incorrect runway. However, as previously stated, the Board believes that these events occurred because the flight crew did not use the available cues on the airport surface during taxi and did not cross-check and confirm the airplane's position on the runway before departure. Also, the flight crewmembers engaged in a nonpertinent conversation during a critical phase of flight (taxi operations), which caused them to lose positional awareness. In addition, before the airplane arrived at the dark runway, the first officer briefed the outage of the runway end identifier lights, he recounted that lights were out during his arrival at LEX early on the morning that preceded the accident flight, and the flight crew most likely read the NOTAM in the flight release paperwork that indicated that the runway 4/22 centerline lights were out of service.

This accident is not the first one involving a wrong runway takeoff in which pilots did not use existing cues to identify the airplane's location on the airport surface or cross-check and verify the airplane's position before takeoff. For example, the final report on the October 31, 2000, Singapore Airlines flight 006 accident (see section 1.18.4) stated that the pilots did not verify the airplane's position on the taxi route as the airplane was turning onto the wrong runway and concluded that the flight crew lost situational awareness and took off from the wrong runway despite numerous available cues that provided information about the airplane's position on the airport. However, the final report for that accident cited a possible reason for the flight crew's actions: the pilots did not adequately review the taxi route to ensure that they understood that the route to the correct departure runway required passing a parallel runway that was under construction and was open only for taxi operations.

Numerous other wrong runway events have occurred. The ASRS database showed 114 reports of incidents from March 1988 to September 2005 in which flight crews of turbojet airplanes lined up on the wrong runway for takeoff. The ASRS reports indicated that the pilots involved in these events, pilots of other aircraft in the area at the time, or air traffic controllers detected the mistake either before or after takeoff. Also, on October 30, 2006, an Alaska Airlines 737 departed from the wrong runway at SEA. According to postincident interviews, the controller instructed the flight crew to taxi the airplane into position and hold on runway 34C, but the captain assumed that the airplane would be taking off from runway 34R. After the airplane departed uneventfully from runway 34R, the controller informed the flight crew that the airplane had departed from the wrong runway.

Most recently, on April 18, 2007, a United Airlines Airbus A320 taxied onto runway 27, which was closed, instead of runway 30, the assigned departure runway, at MIA and began the takeoff roll. A NOTAM, which was included in the flight release paperwork, and the ATIS information broadcast, which the flight crew received, indicated

that runway 27 was closed. Also, the flight crew reported that the airport charts were out and available. As the airplane proceeded down runway 27, the airplane's nose wheel light illuminated a truck flashing its lights. The captain and the first officer stated that they observed the truck at the same time. Simultaneously, the controller queried the flight crew to determine whether the airplane was on runway 30. The flight crew rejected the takeoff, and the airplane continued uneventfully to its destination.

The Comair flight 5191 accident and other wrong runway takeoff events demonstrate that all pilots are vulnerable to this and other types of surface navigation errors. Even when navigation tasks are straightforward and simple, there is a potential for a catastrophic outcome resulting from human error if available cues are not observed and considered during taxi and the airplane's position is not cross-checked at the intended runway. Systemwide interventions, such as improved airport standard markings and technologies to improve pilots' positional awareness while navigating airport surfaces, can help protect against human error during airport surface operations by providing a redundant display of critical information. Such interventions are further discussed in section 2.4.

In addition, the Safety Board is concerned about the breakdown in sterile cockpit discipline in the sequence of events leading to this accident. The pilots' actions with regard to sterile cockpit procedures, specifically, their nonpertinent conversation while the captain was taxiing the airplane, were uncharacteristic with past reports. A first officer who flew with the captain 2 days before the accident described the captain's sterile cockpit discipline as very good and stated that, when a newly trained first officer was occupying the cockpit jumpseat during one of the flight legs, the captain briefed him about sterile cockpit discipline. The first officer was also described as having good sterile cockpit discipline.

On February 7, 2006, the Safety Board issued Safety Recommendation A-06-7, which was the result of the Board's investigation of the Corporate Airlines flight 5966 accident. Safety Recommendation A-06-7 asked the FAA to direct the POIs of all 14 CFR Part 121 and 135 operators to reemphasize the importance of strict compliance with the sterile cockpit rule.[190] Also, the Board notes that sterile cockpit violations are among the types of intentional noncompliance that can be detected through LOSA observations (see section 1.17.3). On January 23, 2007, as a result of its investigation of the October 14, 2004, Pinnacle Airlines flight 3701 accident, the Board issued Safety Recommendation A-07-9, which asked the FAA to require that all 14 CFR Part 121 operators incorporate into their oversight programs periodic LOSA observations and methods to address and correct findings resulting from these observations.[191]

[190] On April 28, 2006, the FAA issued SAFO 06004, "Approach and Landing Accident Reduction: Sterile Cockpit, Fatigue," to emphasize the importance of sterile cockpit discipline. As a result, Safety Recommendation A-06-7 was classified "Closed—Acceptable Action" on November 9, 2006.

[191] On April 13, 2007, the FAA stated that LOSA was not necessarily the only way in which an operator could accomplish oversight of the safety of its operations and that no-notice line checks, for example, offered many of the same advantages as LOSA with regard to the information gained. The FAA also stated its belief that the most effective approach to the underlying safety issues discussed in this recommendation was the effective implementation of SMS, for which a rulemaking project has begun.

2.2.3 Air Traffic Controller Human Factors

Indications of the flight crew's surface navigation error were visible from the tower during two distinct time periods. The first time period occurred when the airplane was stopped at the runway 26 hold short line for 50 seconds, from 0604:33 to 0605:23,[192] during which time the first officer announced that the airplane was ready to depart and the controller issued a takeoff clearance. The airplane had been cleared to taxi to runway 22, and the flight crew was not required to stop the airplane short of runway 26. If the controller had noticed that the airplane had stopped in that location before issuing the takeoff clearance, the controller could have queried the flight crew, issued additional taxi instructions, or closely monitored the airplane's subsequent progress. The controller's postaccident statements indicated that he did not notice that the airplane had stopped short of runway 26. As a result, he missed an opportunity to prevent the flight crew's surface navigation error and subsequent wrong runway takeoff attempt.

The second time period lasted 28 seconds. It began about 0605:56, when the airplane began to align with runway 26, and ended about 0606:24, when the airplane accelerated beyond the maximum airspeed that would have allowed the airplane to remain on the available runway if the flight crew rejected the takeoff and used maximum braking. The airplane's movements during this time were not consistent with the clearance provided by the controller and were a clear sign of a lack of positional awareness on the part of the flight crew. If the controller had been looking out the tower cab window and monitoring the flight, he could have addressed this situation by alerting the flight crewmembers that the airplane was on the wrong runway or, later, by instructing them to reject the takeoff. The controller did not take any such actions. The controller indicated that he did not see the airplane align with runway 26 or begin its takeoff roll because he had turned around to perform the traffic count, which is an administrative record-keeping task.

The Safety Board examined possible reasons why the controller did not notice indications of the flight crew's surface navigation error either during the 50-second window of opportunity, which began about 2 minutes before the accident, or during the 28-second critical window, which began about 39 seconds before the accident. Figure 7 shows a detailed timeline of communications and events that occurred in the 2 minutes before the accident.

[192] Flight crews stop along a taxi route for various reasons, including a perception of potential traffic conflicts, passenger movements in the cabin, and uncertainty about the taxi clearance or the taxi routes. Some stops during taxi are accompanied by radio transmissions to ATC to explain the delay or seek clarification. Some controllers have a heightened sense of awareness when stops are made during taxi depending on the circumstances and the duration.

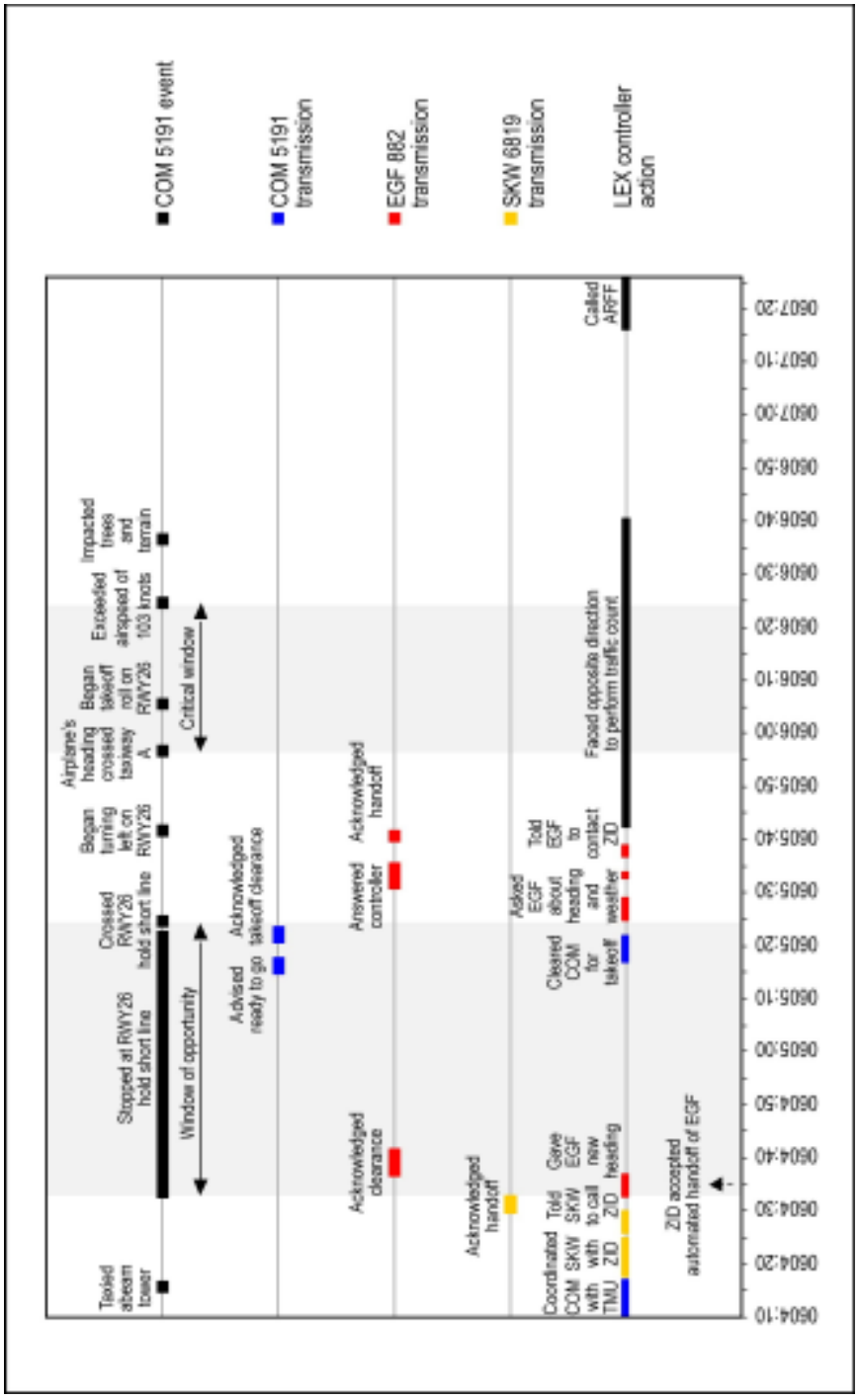


Figure 7. Air Traffic Control Event Timeline

Note: COM, Comair; EGF, American Eagle; SKW, SkyWest; ZID, Indianapolis Air Route Traffic Control Center; TMU, traffic management unit.

2.2.3.1 Window of Opportunity During Which the Airplane Was Stopped Short of the Wrong Runway

On the day of the accident, all LEX tower and radar positions were combined and were being worked by one controller.[193] As a result, the controller had to switch his attention between tower and radar tasks. The controller's tower responsibilities included controlling aircraft operations on the airport surface and during takeoffs and landings,[194] and his primary source of visual information was the view of the airport surface.[195] The controller's radar responsibilities included controlling airplanes in the airspace around the airport,[196] and his primary source of visual information was the DBRITE, which was mounted below the tower cab windows at the local control position. Despite the need to divide his attention between these tasks, the controller's workload at this time was not excessive.

When Comair flight 5191 stopped at the hold short line for runway 26, the controller had just finished obtaining that flight's departure release from the Indianapolis ARTCC's traffic management unit (a tower task) and coordinating a heading change for SkyWest flight 6819 with the ARTCC's LEX sector controller (a radar task). After the Comair flight had stopped, the controller spent 8 seconds vectoring American Eagle flight 882 (a radar task). No ATC communications took place during the next 34 seconds. The first officer of the Comair flight then requested takeoff clearance. The controller immediately issued this takeoff clearance (a tower task), and the first officer repeated the clearance. About 2 seconds later, as the Comair airplane began to roll, the controller asked the flight crewmembers of the American Eagle flight whether they were satisfied with the airplane's present heading or would like a new one to avoid weather (a radar task).

Performance of concurrent tasks requires a division of attention. Some concurrent tasks can be performed simultaneously, but when concurrent tasks draw on different sources of visual information, they require a person to engage in selective attention, which involves the switching of attention back and forth between sources of information associated with each task to update information about the tasks in working memory.[197] The timeline shown in figure 7 indicates the controller's tower and radar tasks during the 50-second window of opportunity, and the controller's communications during this time can be analyzed, along with task requirements, to draw conclusions regarding how the controller was focusing his attention during various time periods.

The controller was facing certain considerations in performing radar-related tasks. For example, because the SkyWest and American Eagle flights were going to be

[193] The decision to staff the LEX ATCT with one controller during the midnight shift is discussed in section 2.5.

[194] The controller's tower responsibilities also included monitoring in-flight aircraft operations within a radius of 4.3 nm and 2,500 feet agl.

[195] Other sources of information that were used by the controller for his tower responsibilities included the DBRITE and flight progress strips.

[196] This airspace was within 35 nm from the surface to 10,000 feet msl and included surrounding airports.

[197] C.D. Wickens, *Engineering Psychology and Human Performance*, New York: HarperCollins, 1992.

using the same route and airspace as they left the local area, the controller needed to ensure a separation of at least 10 miles in between these airplanes (in accordance with an agreement between the LEX ATCT and the Indianapolis ARTCC). Also, the SkyWest flight crew had requested a deviation around an area of precipitation that was located about 10 miles west of LEX, and the controller's communications indicated his anticipation that the American Eagle flight crew might request a similar course deviation. The controller knew that, if this request were made, he would have to coordinate another heading change with the Indianapolis ARTCC's LEX sector controller. These considerations increased the controller's expectation that he would need information from the DBRITE to manage these aspects of his radar responsibilities, which increased the likelihood that he was frequently examining the DBRITE during the 50-second window of opportunity. However, the workload associated with the controller's radar tasks would not have prevented him from periodically looking out the tower cab window.

In contrast, the controller's tower responsibilities at that time had become relatively simple. Because the controller had already obtained the Comair flight's departure release and provided the flight crew with the clearance to taxi to runway 22 (which the first officer acknowledged), the only tower task he had to perform was to clear the airplane for takeoff. The controller did not have to frequently look at the runway environment to perform this task because he would have expected that the flight crew would inform him when the airplane was ready to depart, and he would be able to scan the runway at that time. Because no other traffic was on the airport surface to pose a conflict to the airplane during its taxi, the controller would not have expected much useful information to be obtained by frequently scanning the runway environment, which would have decreased the likelihood that he was frequently looking out the tower cab windows at the runway environment during the 50-second window of opportunity. The Safety Board concludes that the controller did not notice that the flight crew had stopped the airplane short of the wrong runway because he did not anticipate any problems with the airplane's taxi to the correct runway and thus was paying more attention to his radar responsibilities than his tower responsibilities.

Postaccident observations from the LEX ATCT revealed that, from the controller's work station at night, it was somewhat difficult to see whether the CRJ-100 demonstration airplane was located at the hold short line for runway 26, on taxiway A, or at the hold short line for runway 22 because of (1) the proximity of these locations in the controller's visual field as a result of the new taxiway configuration[198] and (2) the reduced visibility of ground texture, linear perspective, and other monocular depth cues that are useful for judging distances beyond 15 to 20 feet. Although the controller had been working at the tower for 17 years and had presumably become an expert at recognizing aircraft positions on the airport surface, the use of former taxiway A5 (redesignated as taxiway A) to reach the runway 22 threshold was new to him because the runway had been shifted and the redesignated taxiway had been in place for only 1 week (four of the controller's shifts)

[198] From the tower cab, the hold short lines for runways 22 and 26 appeared close to each other because they were separated by less than 5º of visual angle.

at the time of the accident.[199] These factors would have made it more difficult for the controller to determine the airplane's exact location.

In addition, the controller was not required to determine that the airplane had reached the departure runway before he cleared the airplane for takeoff; he was only expected to determine that the airplane was at a location that was consistent with its taxi clearance. When the flight crew had stopped the airplane at the runway 26 hold short line, the airplane was in a location that was consistent with its taxi clearance. The controller reported that he did not see the airplane stop in this position. Even if the controller had seen the airplane at that time and noticed that it was not moving, a brief scan of the runway environment would not have informed him of whether the airplane had been stopped only briefly or for a longer period of time. Nevertheless, the controller could have detected that the airplane had stopped short of the wrong runway if he had been monitoring the airplane's progress along the taxi route.

2.2.3.2 Critical Window During Which an Administrative Task Was Performed

After the LEX controller cleared Comair flight 5191 for takeoff, he told American Eagle flight 882 to contact the Indianapolis ARTCC. According to the ATC transcript, the handoff of the American Eagle flight to the Indianapolis ARTCC occurred about 0605:40. About that time, Comair flight 5191, the only airplane for which the controller had responsibility, was turning onto runway 26 and had not yet deviated from the issued taxi clearance. The controller's next active task would be to establish contact with the Comair flight and provide departure services (radar tasks), but he would likely not have expected to perform this task for about 1 minute.[200] This 1-minute pause in active control tasks afforded the controller greater flexibility in terms of his allocation of attention.

The controller stated that, after the handoff of the American Eagle flight to the Indianapolis ARTCC, he began the combined traffic count, which was an administrative record-keeping task.[201] The standard operating procedure at LEX was to perform the traffic count on an hourly basis. However, the controller stated that he normally accumulated flight progress strips throughout the night and performed the traffic count once toward the end of his shift. The controller estimated that the traffic count would take 2 to 5 minutes to complete.[202]

The controller was expecting to be relieved by the incoming day shift controller at 0630, so he most likely wanted to complete the traffic count by that time. However,

[199] When taxiway A north of runway 8/26 was used to reach the runway 22 threshold, the hold short lines for runways 22 and 26 were farther apart in the controller's visual field.

[200] The time between flight crew acknowledgment of the takeoff clearance and the controller's acknowledgment of radar contact was 41 and 78 seconds for the SkyWest and American Eagle departures, respectively.

[201] When the tower was staffed with more than one controller, the controller at the radar data position recorded the radar traffic count, and the controller at the clearance delivery position recorded the tower traffic count. When the midnight shift was staffed with one controller, that controller performed a combined radar and tower traffic count.

[202] As a result, the controller must have expected that he would have to interrupt this administrative task to provide radar services to the Comair flight.

because this task was not urgent or critical to flight safety and the day shift controller was not expected to arrive for more than 20 minutes, the accident controller could have delayed performing the traffic count until after he handed off the Comair flight to the Indianapolis ARTCC. If the controller had monitored the Comair flight during its takeoff, he most likely would have detected, during the 28-second critical window, the flight crew's deviation from the taxi and takeoff clearances, and he could have then warned the flight crewmembers about their mistake and have possibly prevented the accident.

Similar to air traffic controllers, pilots must also prioritize overlapping tasks, and inappropriate prioritization of tasks has often been documented as a factor in aircraft accidents and incidents.[203] Task prioritization can break down under high workload conditions, but the controller's workload was relatively light 1 minute before the accident. As a result, the Safety Board considered other factors that could influence task prioritization to understand the controller's decision to perform an administrative task instead of monitoring the airplane. Research indicated that prioritization of concurrent tasks was strongly affected by procedural requirements and that tasks to be performed at a particular time tended to receive higher priority than nonrequired tasks.[204] The controller was not required to monitor the Comair flight's takeoff or perform the traffic count at that particular time. Because of the lack of a procedural requirement, the controller's prioritization of attention would have been based on other factors. Research indicated that other factors that can affect task prioritization included a task's perceived importance, the acceptability of its present status, and its ease of completion.[205]

The controller assumed that the likelihood of a surface navigation error was small. Before the accident, no air carrier airplane had attempted to take off on runway 26,[206] and the controller had no reason to suspect that a flight crew would attempt to do so. No other traffic was on the airport surface to pose a conflict, so the potential for a ground collision was extremely low. As a result, the controller most likely considered the importance of monitoring the takeoff as low. In addition, the controller's postaccident statements indicated that he had not adopted a practice of consistently monitoring takeoffs whenever possible.

Because the controller performed the traffic count at the end of his shift instead of hourly, the status of this task had become an issue. The controller was nearing the

[203] Research found that 23 percent of major aircraft accidents between 1960 and 1989 involved cockpit task management errors and that 32 percent of the accidents in this category involved pilot deficiencies in task prioritization. For more information, see C. Chou, D. Madhavan, and K. Funk, "Studies of Cockpit Task Management Errors," *International Journal of Aviation Psychology*, vol. 6, pages 307-320, 1996. These researchers also studied aircraft incidents reported through ASRS and found that 35 percent of cockpit task management errors involved task prioritization.

[204] Research on pilot prioritization of in-flight tasks indicated that significant individual differences existed in prioritizing tasks but that the primary factor might be procedural consistency or operating procedures that require a certain task to be performed at a certain time. For more information, see K. Colvin, K. Funk, and R. Braune, "Task Prioritization Factors: Two Part-Task Simulator Studies," *International Journal of Aviation Psychology*, vol. 15, pages 321-338, 2005.

[205] K. Colvin, K. Funk, and R. Braune, 2005.

[206] A 1993 ASRS report indicated a near takeoff on runway 26 by an air carrier airplane (see section 1.18.5).

end of his shift and needed to complete the task, which he viewed as quick and easy, before he could be relieved of his duties. Although the controller decided that the traffic count needed to be performed at that time, the performance of that administrative task was not directly related to safety. Unexpected hazardous events can occur during airport operations, as demonstrated by this accident, and controller monitoring can provide an important redundant safety protection against such events.

The Safety Board concludes that the controller did not detect the flight crew's attempt to take off on the wrong runway because, instead of monitoring the airplane's departure, he performed a lower-priority administrative task that could have waited until he transferred responsibility for the airplane to the next ATC facility.

On April 10, 2007, the Safety Board issued Safety Recommendation A-07-34, which asked the FAA to require all air traffic controllers to complete instructor-led initial and recurrent training in resource management skills to improve controller judgment, vigilance, and safety awareness (see section 1.18.3.2). On July 13, 2007, the FAA stated that it had delivered CRM workshops, posters, and follow-up support to several ATCTs and TRACONs. The FAA also stated that the CRM implementation plan for fiscal years 2007 through 2009 included instructor-led training at "a percentage of" the highest-error-rate terminal and en route facilities and CRM training for initial hires in the FAA Academy and college training initiative programs. The FAA further stated that it would develop plans to train additional controllers on an initial and a recurrent basis.

The Safety Board is encouraged that the FAA has provided CRM training to some ATC facilities but is concerned that such training may not be provided to all controllers, including those at smaller facilities (such as LEX). The Board is also concerned about the FAA's plans for recurrent CRM training at only a percentage of the terminal and en route facilities with the highest error rates. The FAA needs to ensure that all controllers (and not just those at highest-error-rate facilities) receive this training on an initial and a recurrent basis. Pending this action, Safety Recommendation A-07-34 is classified "Open—Acceptable Response."

2.2.3.3 Fatigue

As stated in section 2.2.2.4, potential conditions that can lead to the development of a fatigued state include chronic sleep restriction, acute sleep loss, circadian disruption, and time since awakening. The controller's reported duty times and sleep patterns from August 24 to 26, 2006, were not indicative of a chronic sleep restriction, but they were indicative of acute sleep loss, circadian disruption, and a long time since awakening.

The controller reported that, on August 26, 2006, he awoke at 0540, worked from 0630 to 1430, and took a nap between about 1530 and 1730 (the quality of his sleep during the nap was described as "not real good"). As a result, the controller had slept about 2 hours in the 24 hours that preceded the accident (which is much less than the nominal sleep period of about 8 hours), and he had been continuously awake for more than 12 hours since his nap. In addition, the controller was adapted to sleeping at night, and the accident occurred at a time when he would have normally been asleep and when

circadian factors would tend to diminish alertness. Thus, the controller's recent duty times and sleep patterns indicated that he would have been experiencing some fatigue at the time of the accident. However, a review of ATC tapes found that the controller's communications throughout his shift (including those involving the SkyWest, American Eagle, and Comair flights) were prompt and professional. The review also found that the controller did not yawn during his transmissions or make any phraseology errors (except for not advising the flight crew that taxiway A north of runway 8/26 was closed, as discussed in section 2.6.2).

Nevertheless, reducing daily sleep periods by as little as 2 hours can produce slight decreases in cognitive performance, and greater sleep restrictions can produce more pronounced effects.[207] Fatigue tends to increase preoccupation with single tasks or elements, reduce scanning, increase vigilance errors, impair decision-making, and diminish awareness of one's own degraded performance. These effects tend to have a negative effect on the performance of concurrent tasks.

As discussed in section 2.4.4, the FAA's existing procedures for issuing takeoff clearances allowed the controller to issue the takeoff clearance and scan the runway environment before the airplane crossed the intersecting runway. Also, as discussed in section 2.4.5, the FAA did not have a policy that explicitly required the controller to monitor airplanes during takeoff or a policy that explicitly stated that the controller was required to give higher priority to the monitoring of takeoffs rather than the performance of an administrative task. FAA Order 7110.65, "Air Traffic Control," states that actions that are most critical to safety should be performed first, but this policy leaves a great deal of interpretation to the individual controller.

The controller was not in the habit of monitoring takeoffs. The controller stated that his decision to monitor an airplane during takeoff depended on traffic spacing and the other tasks he had to perform. On the basis of this statement, the controller's decision to perform the traffic count when Comair flight 5191 was taking off could have been consistent with his normal practice for monitoring departing airplanes.

The Safety Board concludes that the controller was most likely fatigued at the time of the accident, but the extent that fatigue affected his decision not to monitor the airplane's departure could not be determined in part because his routine practices did not consistently include the monitoring of takeoffs. The Safety Board further concludes that FAA operational policies and procedures at the time of the accident were deficient because they did not promote optimal controller monitoring of aircraft surface operations.

On April 10, 2007, the Safety Board issued Safety Recommendations A-07-30 and -31 to the FAA to address its concerns about the potential impact of fatigue on air traffic controller performance.[208] Safety Recommendation A-07-30 asked the FAA to work with NATCA to reduce the potential for controller fatigue by (1) revising controller

[207] H.P.A. Van Dongen, G. Maislin, et al., 2003.

[208] Also on April 10, 2007, the Safety Board issued Safety Recommendation A-07-32 to NATCA to address this issue (see section 1.18.3.2). The recommendation is currently classified "Open—Await Response."

work scheduling policies and practices to provide rest periods that are long enough for controllers to obtain sufficient restorative sleep and by (2) modifying shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance. Safety Recommendation A-07-31 asked the FAA to develop a fatigue awareness and countermeasures training program for controllers and personnel who are involved in the scheduling of controllers for operational duty that addresses the incidence of fatigue in the controller workforce, causes of fatigue, effects of fatigue on controller performance and safety, and the importance of using personal strategies to minimize fatigue.

On July 5, 2007, the FAA responded to Safety Recommendations A-07-30 and -31. The FAA stated that it had convened a working group to develop shift rotation and scheduling guidelines and that NATCA would be invited to participate in the group. The FAA also stated that it would develop, within 12 months, and implement a fatigue awareness and countermeasures training program to be used by all FAA Air Traffic Organization operational service units. Pending (1) the development of guidance for controller work scheduling policies and practices to provide rest periods that are long enough for controllers to obtain sufficient restorative sleep and (2) the modification of shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance, Safety Recommendation A-07-30 is classified "Open—Acceptable Response." Pending the development and implementation of a fatigue awareness and countermeasures training program for controllers and personnel involved in the scheduling of controllers for operational duty, Safety Recommendation A-07-31 is classified "Open—Acceptable Response."

2.2.3.4 Summary of Air Traffic Controller Human Factors

The concurrent radar and tower tasks that required the controller to divide his attention occurred during the window of opportunity when the controller could have, but did not, notice that the airplane was stopped short of runway 26. After the controller transferred control of American Eagle flight 882 to the Indianapolis ARTCC, he did not have any further active radar duties. However, after the transfer, the controller performed an administrative task—the traffic count—instead of monitoring the departure of Comair flight 5191. The controller had turned around in the tower cab to perform this task before the start of the critical window. At that time, the airplane had not yet deviated from the issued clearances. However, at the end of the critical window, the airplane had accelerated beyond the maximum airspeed that would have allowed the airplane to remain on the available runway if the flight crew rejected the takeoff and used maximum braking. Thus, at that point, the controller missed his final opportunity to notice the flight crew's error in enough time to take action to prevent the accident.

The controller most likely considered the importance of monitoring the Comair flight's takeoff as low because he assumed that there was little opportunity for a surface navigation error and no other traffic was on the airport surface to pose a conflict. On the other hand, the controller most likely considered that the traffic count was a higher priority at that time because he was nearing the end of his shift and needed to complete the task before he could be relieved of his duties. The controller did not appropriately prioritize

his tasks because the traffic count was not directly related to safety, but monitoring the takeoff would have provided an important safety protection.

Because of the nature of their responsibilities, controllers are expected to be able to appropriately prioritize and perform concurrent tasks. Some controllers may not recognize the critical importance of their monitoring efforts in providing a redundant safety protection against unexpected flight crew errors and other threats to flight safety. This issue is further discussed in section 2.4.4.

The controller's recent duty times and sleep patterns indicated that he was most likely experiencing fatigue at the time of the accident. Also, the circumstances of this accident suggested that task prioritization could be improved by modifying existing FAA guidelines on duty priority so that they explicitly state that active control tasks with a direct flight safety benefit, such as monitoring departing and arriving aircraft, are a higher priority than administrative record-keeping tasks, such as a traffic count. This issue is further discussed in section 2.4.5.

2.3 Survival Factors

2.3.1 Impact Sequence and Injury Information

The airplane's impact with a berm located about 265 feet from the departure end of runway 26 caused the airplane to become momentarily airborne. No airplane debris (except for a main landing gear door) was found before the berm, indicating the airplane structure was intact before this point. Ground scars from the left main and nose landing gears were found about 620 feet from the end of the runway. The airplane then became airborne again, and the cockpit and the left wing impacted an initial group of trees located about 900 feet from the end of the runway. This impact caused the cockpit to break open and the left wing fuel tank to rupture, allowing a fuel-air mixture to ignite. The airplane then impacted the ground about 1,250 feet from the end of the runway, as evidenced by ground scars from the entire lower surface of the airplane.

The airplane then slid 400 feet and struck two large diameter trees. The impacts breached the passenger cabin, separating it into two sections and allowing a large amount of fuel, fuel vapor, and fire to enter the cabin. The fuselage traveled another 150 feet before coming to a stop. The airplane structure continued to burn, and the fire eventually consumed the entire fuselage and cabin interior.

The simultaneous impacts with two large diameter trees caused numerous blunt force fatal injuries to passengers. One of these tree strikes occurred on the left side of the fuselage several rows aft of the main cabin door.[209] The other tree strike occurred in the area where the left inboard wing attached to the fuselage. This tree breached the left wing fuel tank and the cabin in the area of the left overwing exit, cut through the cabin as the airplane continued to slide, and exited the right side of the aft cabin. Figure 8 shows the approximate tree strike areas in the cabin.

[209] This tree was uprooted and carried with the airplane to its final location.

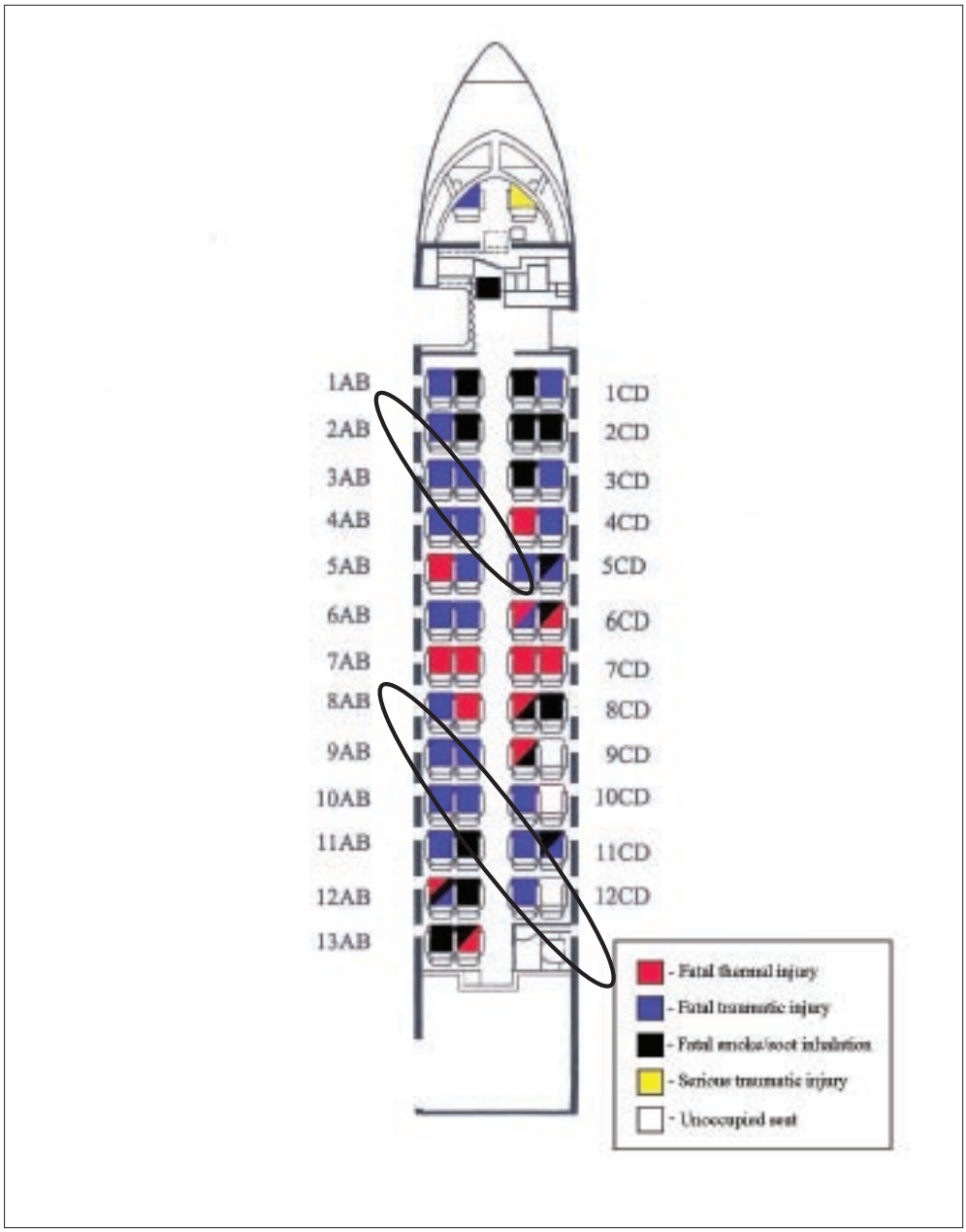


Figure 8. Approximate Tree Strike Areas and Injury Information

Note: On the basis of body location information and autopsy results, the Safety Board determined that, before the attempted takeoff, the passengers assigned to seats 2A and 2B most likely switched seats, the passenger assigned to seat 10D most likely moved to seat 7B, and the nonrevenue passenger most likely took seat 12B.

Note: Seat positions showing more than one color indicate more than one reported major pathologic finding in the autopsy reports.

The captain's body was found in the forward area of the passenger cabin. The seriousness of the captain's blunt force injuries would have precluded him from initiating any postaccident movement. Thus, the captain (and his seat) must have been separated from the cockpit during the impact sequence.

The first officer was found in the remnants of his seat secured by the seat's restraint system. He was extricated from the cockpit wreckage by first responders to the accident scene and transported to the hospital, as discussed in section 2.3.2.

The flight attendant's body was found close to his jumpseat. His autopsy report and those of several passengers in the forward area of the cabin showed a relative lack of blunt force injuries and evidence of smoke inhalation. These findings indicated that these occupants survived the impact but succumbed to the effects of the postcrash fire and smoke. It was not possible to determine the length of time that these occupants survived, but it is important to note that all of these occupants were found close to their seats.

Several passengers who were seated in the forward left part of the cabin were found near each other in the aft right part of the cabin. It is likely that the forward tree strike caused these passengers and their seats to be displaced. Most of these passengers sustained fatal blunt force injuries.

Most of the passengers seated in rows 7 through 9 (the overwing exit row and the rows immediately in front of and in back of it) were killed immediately by the flash fire that occurred after the left wing fuel tank was breached by the aft tree strike and fuel, fuel vapor, and fire entered the cabin.

Two passengers were found outside of the cabin on the left side of the fuselage. These passengers sustained fatal thermal injuries, and neither sustained serious blunt force injuries. Evidence indicated that the passengers were likely thrown outside (through the break in the fuselage caused by the aft tree strike) when the airplane came to a stop.

Several passengers who were seated in the aft cabin sustained some blunt force injuries, and most showed evidence of smoke inhalation. It was not possible to determine the length of time that these passengers survived, but it is important to note that all of the passengers were found close to their seats.

2.3.2 Emergency Response

According to the aircraft performance study for this accident, the airplane struck trees and terrain west of the airport about 0606:35. The sounds of the accident took about 5 seconds to reach the tower. The controller stated that, after hearing these sounds, he saw a fire west of the airport. The ATC transcript showed that the controller activated the crash phone about 0607:17. Thus, about 37 seconds had elapsed between the time that the accident sounds could be heard in the tower and the time that the controller activated the crash phone. During this time, the controller had to turn around and look outside the tower cab window; assess the situation; and recognize that, even though the airplane

had been cleared to take off from runway 22, the airplane was actually located off the departure end of runway 26. The ATC transcript showed that the airport fire department responded to the crash phone about 0607:22. According to the ATC transcript, the controller announced an "alert three" and indicated that a Comair jet was located at the west side of the airport just off the approach end of runway 8. By providing clear and accurate information about the airplane's status and location, the controller's actions complied with the LEX ATCT's standard operating procedures and letter of agreement with the airport board regarding emergency notifications.

The first emergency responders to arrive on scene were a LEX public safety officer and a police officer from the city of Lexington. They arrived (independently of each other) in the general vicinity of the accident about 5 1/2 minutes after receiving notification of the accident and reached the fuselage within 3 1/2 minutes despite restricted visibility caused by tall vegetation near the accident site. The first ARFF vehicle arrived on scene about 11 minutes after alert 3 notification using route information provided by another LEX public safety officer (who was in the general vicinity of the accident site but was not yet on scene). This route was the most effective direct route available to the accident site. This ARFF vehicle immediately began fire suppression and knocked down most of the fire. The second ARFF vehicle arrived on scene shortly afterward and began additional fire suppression. The LEX operations center incident report showed that the fire was controlled about 3 minutes after the first ARFF vehicle arrived on scene. The assistant ARFF chief (who arrived on scene in the first ARFF vehicle) stated that, upon reaching the airplane, its top was gone, and its sides were mostly gone. Other first responders reported that the cabin interior was completely involved (that is, completely on fire) at the time of their arrival on scene.

The LEX public safety officer and the police officer from the city of Lexington were able to free the first officer from the cockpit wreckage. Another LEX public safety officer and the city of Lexington police officer transported the first officer to the hospital in a sport-utility vehicle instead of waiting for an ambulance. This LEX public safety officer estimated that they arrived at the hospital (located about 7 miles from the accident site) before 0630. Because of the serious traumatic injuries that the first officer sustained from the accident, it was imperative that he be quickly transported to and receive immediate treatment from a trauma center. The Safety Board concludes that the first officer's survival was directly attributable to the prompt arrival of the first responders; their ability to extricate him from the cockpit wreckage; and his rapid transport to the hospital, where he received immediate treatment. The Safety Board further concludes that the emergency response for this accident was timely and well coordinated.

2.3.3 Summary of Survival Factors

The Safety Board's definition of a survivable accident is as follows:[210]

> An accident in which the forces transmitted to the occupant(s) through the seat and restraint system do not exceed the limits of human tolerance to abrupt accelerations and in which the structure in the occupants' immediate environment remains substantially intact to the extent that a livable volume is provided for the occupants through the crash sequence.

The captain and the passengers who received fatal blunt force injuries as a result of the simultaneous tree strikes were clearly in areas of the airplane in which the forces transmitted to the occupants exceeded the limits of human tolerance. Most of the passengers in the overwing area of the cabin did not experience similar forces; however, the large amount of fuel, fuel vapor, and fire forced into the cabin by the aft tree strike made the cabin environment immediately unsurvivable for those passengers. The flight attendant and most of the passengers in the forward and aft areas of the cabin also did not experience forces that exceeded the limits of human tolerance and maintained a livable volume of occupiable space for an undetermined amount of time. As stated in section 2.3.1, the flight attendant and these passengers were found close to their assigned seats.

Because the impact forces did not exceed the limits of human tolerance and occupiable space was maintained for some of the airplane occupants, this accident was partially survivable. However, the environment inside the airplane deteriorated quickly as a result of the postcrash fire and smoke, which did not allow sufficient time or means for those occupants to evacuate.

2.4 Efforts to Mitigate Airport Surface Operation Errors

Surface operation errors, including those that lead to wrong runway takeoff events, can be mitigated in several ways, such as improved flight deck procedures, the implementation of cockpit moving map displays or cockpit runway alerting systems, improved airport surface marking standards, and ATC policy changes. These systemwide interventions, which are discussed in sections 2.4.1 through 2.4.5, can provide the necessary redundancy to reduce the opportunity for human error during surface operations and, if an error were to occur, to stop it before it becomes catastrophic. These interventions can also help prevent runway incursions, which is an issue on the Safety Board's list of Most Wanted Transportation Safety Improvements.

[210] This definition was cited in the Safety Board's 1981 special study on cabin safety in large transport aircraft. According to the study, the definition (1) was developed using aviation crash injury research by Cornell University and aviation safety engineering and research by the Flight Safety Foundation and (2) was used in the *Aircraft Crash Survival Design Guide*, which was prepared by the U.S. Army Research and Technology Laboratories along with other Federal agencies. The definition has been used by the Board since that time to determine the survivability of accidents. In addition, the definition appeared in the Board's 2001 safety report on the survivability of accidents involving Part 121 U.S. air carrier operations from 1983 to 2000.

2.4.1 Flight Deck Procedures

Well-designed flight deck procedures can be an effective countermeasure against surface operation errors. After this accident, the Safety Board recognized the need to improve industry standards for confirming an airplane's position at the departure runway before takeoff and, on December 12, 2006, issued Safety Recommendation A-06-83. This recommendation asked that the FAA require all Part 121 operators to establish procedures requiring all crewmembers on the flight deck to positively confirm and cross-check the airplane's location at the assigned departure runway before crossing the hold short line for takeoff.

On April 16, 2007, the FAA issued SAFO 07003, "Confirming the Takeoff Runway," in response to Safety Recommendation A-06-83. According to the SAFO, its purpose is to emphasize the importance of implementing standard operating procedures and training for flight crews to ensure that an airplane is at the intended runway.

SAFO 07003 was aimed at directors of safety, directors of operations, fractional ownership program managers, trainers, and pilots. The SAFO stated that pilots should positively confirm and cross-check the takeoff runway and the airplane's location at the assigned departure runway before crossing the hold short line and while in the takeoff position. The SAFO further stated that airplane-specific standard operating procedures should be established, implemented, and supported by pilot training that uses all available resources to confirm and cross-check an airplane's position. The SAFO mentioned that these resources included the HSIs, which can confirm that an airplane's position is where the flight crew intended, and air traffic controllers, who can help confirm an airplane's position during taxi or at a hold short line.

The Safety Board is encouraged that the FAA is providing renewed emphasis about the importance of cross-checking and confirming an airplane's position on a runway. The Board also notes that SAFO 06013, "Flight Crew Techniques and Procedures That Enhance Pre-takeoff and Takeoff Safety" (see section 1.18.2.2), addressed the issue of training and procedures for improving safety during taxi operations. This SAFO referenced AC 120-74A, "Parts 91, 121, 125, and 135 Flightcrew Procedures During Taxi Operations," which outlined best practices for surface operations. The AC indicated that these best practices include sterile cockpit procedures to protect against human error and procedures to maximize "heads-out" time for both pilots to provide necessary redundancy.

The FAA's issuance of SAFO 07003 addressed the intent of Safety Recommendation A-06-83. However, SAFOs are, by definition, advisory only, and the recommendation asked the FAA to require all Part 121 operators to establish procedures requiring flight crewmembers to positively confirm and cross-check an airplane's location at the assigned departure runway before crossing the hold short line for takeoff. Also, the Board's survey of Part 121 operators found that many did not include the procedures recommended in SAFO 06013, which had been issued in September 2006. SAFO guidance may be an acceptable alternate response to a Board recommendation if an FAA survey finds that all Part 121 operators have implemented the recommended procedures.

Because the decision to implement a SAFO rests with an operator and because of the importance to flight safety that the information in SAFO 07003 (as well as SAFO 06013) be required and extended to Part 91K[211] and 135 operators, Safety Recommendation A-06-83 is classified "Closed—Acceptable Alternate Action/Superseded." In addition, the Safety Board concludes that a standard procedure requiring Part 91K, 121, and 135 pilots to confirm and cross-check that their airplane is positioned at the correct runway before crossing the hold short line and initiating a takeoff would help to improve the pilots' positional awareness during surface operations. Therefore, the Safety Board believes that the FAA should require that all 14 CFR Part 91K, 121, and 135 operators establish procedures requiring all crewmembers on the flight deck to positively confirm and cross-check the airplane's location at the assigned departure runway before crossing the hold short line for takeoff. This required guidance should be consistent with the guidance in AC 120-74A and SAFOs 06013 and 07003.

In addition, after the accident, the Safety Board also recognized the need to improve industry standards regarding takeoffs at night on unlighted runways. As a result, on December 12, 2006, the Board issued Safety Recommendation A-06-84, which asked the FAA to require all Part 121 operators to provide specific guidance to pilots on the runway lighting requirements for takeoff operations at night.

On May 11, 2007, the FAA issued InFO 07009, "Runway Lights Required for Night Takeoffs in Part 121." This InFO recognized that, even though runway lighting varied among airports and runways, every pilot operating under Part 121 needed to understand the following: (1) pilots should not take off at night on a runway without lights; (2) pilots must check NOTAMs for runway light outages and taxiway and runway closures, and takeoffs are not permitted on closed runways; and (3) a pilot must think beyond pertinent NOTAMs because inoperative runway lights do not necessarily cause a runway to be closed by the airport authority, or a runway may be unusable even if its runway lights are fully operational. The InFO recommended that Part 121 directors of safety, directors of operations, trainers, and pilots collaborate to make these three points clearly understood by their flight crews and include these points in their pilot operating manuals, training programs, and plans for any night takeoff.

Even though the information in InFO 07009 is responsive to Safety Recommendation A-06-84, InFOs are advisory only, and the recommendation asked the FAA to require Part 121 operators to provide pilot guidance on runway lighting requirements for night takeoff operations. However, if the FAA can determine, by surveying all Part 121 operators, that the guidance in the InFO has been adopted, then the Safety Board could consider the InFO to be an acceptable alternative action to the recommendation. Pending the results of an FAA survey of all Part 121 operators to determine whether they have adopted the guidance in InFO 07009, Safety Recommendation A-06-84 is classified "Open—Acceptable Alternate Response."

Finally, in its report on the February 16, 2005, crash of a Cessna Citation 560 in Pueblo, Colorado, the Safety Board discussed the need for pilots to receive training in

[211] Title 14 CFR 91 Subpart K applies to fractional ownership operations.

monitoring skills and have opportunities to practice these skills.[212] On February 27, 2007, the Board issued Safety Recommendation A-07-13, which asked the FAA to "require that all pilot training programs be modified to contain modules that teach and emphasize monitoring skills and workload management and include opportunities to practice and demonstrate proficiency in these areas."[213] If this recommendation were implemented, pilots would receive training that would not only benefit in-flight operations but also airport surface operations.

2.4.2 Technological Initiatives

Advances in technology can provide pilots with improved positional awareness while navigating airport surfaces. Such technologies were discussed and illustrated at the Safety Board's Runway Incursion Forum in March 2007. Cockpit moving map displays in which the aircraft's position is superimposed on a map of the airport surface, including all runways, taxiways, and terminal areas, would help pilots orient themselves during navigation if they were to become lost, thus mitigating surface navigation errors. A cockpit moving map display could be an effective countermeasure against the type of perceptual error and confirmation bias that occurred with this accident. Efforts to establish digital maps of airports were included as part of the FAA's Safe Flight 21 program, and cockpit-based tools for surface navigation were addressed in the FAA's 2002 Blueprint for Runway Safety. In addition, research showed that, if airborne electronic map displays were extended to airport surface navigation, they could significantly decrease navigational errors, such as wrong turns in low visibility conditions.[214]

On March 23, 2007, the FAA announced that it was accelerating the certification process to facilitate the installation in air carrier cockpits of class 2 electronic flight bags (EFB), which are portable devices that can display various textual and graphical data, including moving maps.[215] The FAA's decision to accelerate the certification process and allow class 2 EFBs to be used for ground operations was the result of the agency's recognition that the requirements for the ground use of these devices could be relaxed compared with the more stringent class C standards for the airborne use of the devices. The FAA's decision to relax the standards for the ground use of class 2 EFBs was partly the result of the agency's review of human factors research on the safety benefits of these systems. According to the FAA, the research showed that pilots had better awareness of their position on the airport's surface using an "own ship" position display, and recent

[212] National Transportation Safety Board, *Crash During Approach to Landing, Circuit City Stores, Inc., Cessna Citation 560, N500AT, Pueblo, Colorado, February 16, 2005*, Aircraft Accident Report NTSB/AAR-07/02 (Washington, DC: NTSB, 2007). The report includes a discussion of the Safety Board's previous work in the area of pilot monitoring.

[213] On May 17, 2007, the FAA stated that 14 CFR Part 61 and the Aircraft Type Rating Practical Test Standard specifically addressed the CRM requirement for airman certification and checking. The FAA also stated that it would consider identifying in its work program a list of required inspections that would reemphasize to regional and flight standards district office managers the need to validate the training that is already required and verify its effectiveness.

[214] V. Battiste, M. Downs, and R.S. McCann, "Advanced Taxi Map Display Design for Low-Visibility Operations," *Proceedings of the Human Factors and Ergonomics Society,* pages 997-1001, 1996.

[215] Class 2 EFBs operate using the airplane's power system.

tests demonstrated that pilots typically glanced at such displays and then quickly looked out their windows to verify that information visually, thus eliminating the concern that pilots would be "heads down" too long for safe operations.

The FAA expected to have guidance on its streamlined certification process for the ground use of class 2 EFB moving map displays by the end of April 2007. (As of July 3, 2007, this guidance had not been issued.) The class C certification standards, which were established in 2003, will remain the same for these devices, but the new certification process is expected to lower the cost for their deployment and implementation.

In addition to cockpit moving map displays, the Safety Board reviewed other available technologies that might have alerted the accident flight crewmembers about their surface navigation error. For example, after the Singapore Airlines flight 006 accident, Boeing developed a wrong runway alert that compares the runway selected in the flight management computer (FMC) with the airplane's position or heading at the time of takeoff. This optional upgrade to EICAS software annunciates a cautionary EICAS alert when a takeoff is attempted on a runway that is not the FMC-selected runway.[216]

Also, Honeywell developed the runway alert and advisory system (RAAS), which is a software addition to the company's enhanced ground proximity warning system (EGPWS). RAAS does not require the installation of additional hardware but does require an airplane to be equipped with a global positioning system. RAAS uses the same runway database as EGPWS to provide an aural advisory to pilots when their airplane is approaching or is on a runway during taxi operations. The RAAS system also provides pilots with an aural advisory when their airplane is on a runway of an operator-defined insufficient length or if the airplane is positioned for an intersection departure of insufficient length. In addition, RAAS provides an aural advisory to pilots if a takeoff is attempted on a taxiway. Research conducted by Honeywell indicated that RAAS could mitigate flight crew surface navigation errors that could lead to wrong runway takeoffs. Currently, eight CRJ airplanes have RAAS installed.

The Safety Board is encouraged by the FAA's actions with regard to cockpit moving map displays for surface navigation and cockpit runway alerting systems. However, these technologies have not been mandated despite their demonstrated safety benefits. These technologies need to be considered in the same category as existing technological interventions such as the traffic alert and collision avoidance system (commonly referred to as TCAS) and EGPWS. The Safety Board concludes that the implementation of cockpit moving map displays or cockpit runway alerting systems on air carrier aircraft would enhance flight safety by providing pilots with improved positional awareness during surface navigation. Therefore, the Safety Board believes that the FAA should require that all 14 CFR Part 91K, 121, and 135 operators install on their aircraft cockpit moving map displays or an automatic system that alerts pilots when a takeoff is attempted on a taxiway or a runway other than the one intended.

[216] According to Boeing, 14 air carriers currently have airplanes equipped with this alert.

2.4.3 Airport Surface Marking Standards

In 2002, the FAA sponsored a study to determine whether paint markings would improve the situational awareness of pilots taxiing on an airfield. The study, which was undertaken by the Mitre Corporation, found that enhanced taxiway centerline markings and surface painted holding position signs (see figure 5) were effective in increasing runway awareness among transport-category pilots.

The FAA is expected to modify its airport marking standards according to the enhanced taxiway centerline marking recommendations from the Mitre Corporation's January 2005 report. Specifically, the FAA is requiring that, by June 30, 2008, all Part 139 airports with 1.5 million or more annual passenger enplanements have enhanced taxiway centerline markings before each runway holding position.[217]

According to AC 150/5340-1J, "Standards for Airport Markings," the enhanced taxiway centerline markings were designed to make hold short lines more conspicuous to pilots and help prevent a loss of situational awareness. The markings were also intended to alert pilots that they were approaching a runway holding position and that they "should go into a 'heads-up' mode of operation until they determine the exact location of the holding position."[218]

Even though the FAA-sponsored study found that surface painted holding position signs were effective in increasing positional awareness for pilots, the FAA did not modify its requirement for these holding position signs. Currently, the signs are only required where the width of the holding position on the taxiway is greater than 200 feet. From a human factors standpoint, surface painted holding position signs provide pilots with an unambiguous cue of their position on the airport surface. The central location of these position signs (adjacent to the taxiway centerline) increases their conspicuity, providing a critical redundancy to existing signage.

The Safety Board is encouraged by the FAA's plan to incorporate enhanced taxiway centerline markings at airports with 1.5 million or more annual passenger enplanements. However, the Board is concerned that other Part 139 airports will not be required to implement these markings and that surface painted holding position signs will still only be required where the width of the holding position on the taxiway is greater than 200 feet. The Safety Board concludes that enhanced taxiway centerline markings and surface painted holding position signs provide pilots with additional awareness about the runway and taxiway environment. Therefore, the Safety Board believes that the FAA should require that all airports certificated under 14 CFR Part 139 implement enhanced taxiway centerline markings and surface painted holding position signs at all runway entrances.

---

[217] According to the FAA's passenger enplanement data for 2005 (the most recent data available), these markings will be required at 75 airports. LEX is not one of those airports; during 2005, it had about 0.5 million passenger enplanements.

[218] AC 150/5340-1J also stated, "installation at other airports is at the option of the airport operator. If an airport operator decides to exercise this option, the enhanced markings must be installed at all holding positions on the airport."

2.4.4 Taxi and Takeoff Clearances

As stated in section 2.2.1.1, 14 CFR 91.129(i) permits pilots, after receiving taxi clearance, to cross all intersecting runways along the taxi route (without stopping) except for the assigned departure runway. On July 6, 2000, the Safety Board issued Safety Recommendations A-00-67 and -68, which asked, in part, that the FAA (1) amend 14 CFR 91.129(i) to require that all runway crossings be authorized only by specific ATC clearance and (2) amend FAA Order 7110.65 to require that, for aircraft that need to cross multiple runways, air traffic controllers issue an explicit crossing instruction for each runway after the previous runway has been crossed. The Board classified these safety recommendations "Open—Unacceptable Response" on April 11, 2006.

If these safety recommendations had been implemented before this accident, the controller would have been required to issue a specific taxi clearance for the airplane to cross runway 26 and then issue a specific taxi clearance for the airplane to continue taxiing to runway 22. These procedures would have provided the flight crew with better awareness of the airplane's position along the taxi route and would have required the controller to visually observe the airplane's position and monitor the taxi as the airplane progressed toward the departure runway. Thus, the flight crew's surface navigation error might have been prevented. In addition, Mitre reports cited pilot and controller concerns about the adequacy of runway crossing requirements, and most of these pilots and controllers thought that it would be beneficial to safety to modify 14 CFR 91.129(i) so that it required a specific clearance for each runway crossing.[219] The Safety Board concludes that this accident demonstrates that 14 CFR 91.129(i) might result in mistakes that have catastrophic consequences because the regulation allows an airplane to cross a runway during taxi without a pilot request for a specific clearance to do so. Therefore, the Safety Board reiterates Safety Recommendations A-00-67 and -68.

In addition, no FAA guidance specifically prohibits issuing a takeoff clearance until all intersecting runways to the departure runway have been crossed. On January 4, 2007, the LEX air traffic manager issued a notice that stated that controllers at the tower were not to issue takeoff clearances for runway 22 until the departing airplanes were observed to have completely crossed runway 26.[220] Such guidance would benefit other airports with intersecting runways. On June 1, 2007, the FAA issued Notice N JO 7110.468 to amend the required phraseology for issuing departure instructions. According to this notice, a controller has to specifically clear an airplane across all intervening runways before issuing a takeoff clearance. However, this guidance does not instruct controllers to wait until an airplane has crossed the runways before issuing the takeoff clearance.

---

[219] (a) *Reports by Airline Pilots on Airport Surface Operations: Part 2. Identified Problems and Proposed Solutions for Surface Operational Procedures and Factors Affecting Pilot Performance*, Technical Report No. MTR94W0000060.v2, McLean, Virginia: Mitre Corporation, 1994; and (b) *Reports by Air Traffic Control Tower Controllers on Airport Surface Operations: The Causes and Prevention of Runway Incursions*, Technical Report No. MTR98W0000033, McLean, Virginia: Mitre Corporation, 1998.

[220] In addition, in its July 17, 1989, letter transmitting Safety Recommendation A-89-74 (see section 1.18.3.1), the Safety Board noted that the controllers at HOU were required to observe airplanes cross the approach end of runway 17 before issuing a clearance for takeoff for runway 12. This requirement was the result of two pilot deviation events in early 1989 that involved departures of U.S. air carrier airplanes from the wrong runway at the airport.

The Safety Board concludes that, if controllers were required to delay a takeoff clearance until confirming that an airplane has crossed all intersecting runways to a departure runway, the increased monitoring of the flight crew's surface navigation would reduce the likelihood of wrong runway takeoff events. Therefore, the Safety Board believes that the FAA should prohibit the issuance of a takeoff clearance during an airplane's taxi to its departure runway until after the airplane has crossed all intersecting runways.

2.4.5 Controller Monitoring Responsibility

FAA Order 7110.65, paragraph 2-1-2, "Duty Priority," states that controllers should "give first priority to separating aircraft and issuing safety alerts" and that "good judgment shall be used in prioritizing all other provisions of this order based on the requirements of the situation at hand." Visual monitoring of takeoffs and landings is not specifically required by the order, so a controller's decision whether to monitor a takeoff or landing is thus left to his or her judgment.

Unless other active, flight safety-related control tasks demand attention, controllers should visually monitor departing and arriving airplanes because such monitoring can allow the detection of unexpected threats to flight safety, including surface navigation errors. Thus, the monitoring of takeoffs and landings should have a higher priority than performing administrative tasks because such tasks, although required, do not directly affect flight safety, whereas visual monitoring of takeoffs and landings provides a safety protection.

The Safety Board recognizes that controllers may not be able to continuously monitor all takeoffs and landings in their area of operations. Research on performance criteria for ATC specialists indicated that local (tower) controllers spent about 38 percent of their time looking out of tower cab windows.[221] These controllers were looking at the DBRITE and flight progress strips during most of their other time, which was necessary because these sources of information were routinely changing and thus required visual attention. Even though controllers cannot continuously monitor departing and arriving airplanes, controllers can prioritize their duties so that they give priority to monitoring tasks over the performance of administrative tasks.

The LEX controller stated that he monitored the takeoff of departing airplanes when arriving airplanes were on final approach so that he could ensure that the departing airplanes took off in time to maintain adequate separation. The controller stated that he might decide to watch other airplanes take off but that this decision depended on whether he needed to attend to other duties. The controller's decision to perform the traffic count instead of monitoring the Comair flight's departure, in addition to his description of his normal monitoring practices for departing airplanes, suggested that he did not regard the visual monitoring of takeoffs and landings as a necessary flight safety activity. However,

[221] K. Cardosi and A. Yost, *Controller and Pilot Error in Airport Operations: A Review of Previous Research and Analysis of Safety Data*, Technical Report No. DOT/FAA/AR-00/51 (Washington, DC: Department of Transportation, 2001).

after the accident, the controller acknowledged that it might have been possible for him to detect that the accident airplane was on the wrong runway if he had been looking out the tower cab windows.

Administrative tasks should not have priority over radar and tower monitoring tasks. The Safety Board concludes that, if controllers were to focus on monitoring tasks instead of administrative tasks when aircraft are in the controller's area of operations, the additional monitoring would increase the probability of detecting flight crew errors. Therefore, the Safety Board believes that the FAA should revise FAA Order 7110.65, "Air Traffic Control," to indicate that controllers should refrain from performing administrative tasks, such as the traffic count, when moving aircraft are in the controller's area of responsibility.

2.5 Air Traffic Control Staffing

In August 2005, an operational error occurred during the midnight shift at RDU, which resulted in a loss of separation between a departing and an arriving airplane. At the time, one controller was performing radar and tower functions in the tower cab. The FAA attributed this incident to "controller situational awareness and actions," specifically, the controller's "failure to maintain constant surveillance and awareness of [radar] displays and traffic situation, failure to comprehend and project the future status of displayed data, and failure to provide attention to detail necessary for the safe operation of aircraft under control." The FAA's final report on the operational error described the traffic situation as "moderately difficult" because the controller was handling nine airplanes (one departure, six arrival, and two taxiing airplanes) and thunderstorms were in the airspace, which led the controller to vector one of the airplanes off of a standard arrival route.

As a result of this incident, the FAA issued verbal guidance in late August 2005 indicating that all facilities with radar and tower responsibilities were to be staffed with two controllers during the midnight shift so that the functions could be split.[222] In November 2005, the LEX air traffic manager notified his staff by e-mail about this guidance.

Staffing during the midnight shift at LEX (0000 to 0800) was frequently not in compliance with this guidance. The midnight shift at LEX was staffed with one controller until January 2006. Between January and March 2006, the midnight shift was staffed with two controllers 40 percent of the time. In April 2006, the shift was again staffed with one controller because traffic had increased during the day and swing shifts and the second

[222] As stated in section 1.10.2.1, in November 2006 the FAA issued Notice N JO 7210.639 to formalize this verbal guidance.

midnight controller was needed on those shifts.[223] As a result of this staffing change, only one controller was performing both radar and tower functions at the time of the accident.

As discussed in section 2.2.3.1, the controller's combined radar and tower responsibilities imposed concurrent tasks, which required him to engage in selective attention during the minutes before the accident. However, the controller's performance of concurrent tasks should not have precluded adequate monitoring of Comair flight 5191 during its attempted takeoff. As discussed in section 2.2.3.2, after he transferred responsibility of American Eagle flight 882 to the Indianapolis ARTCC, the controller's sole operational responsibility was the Comair flight. Thus, no radar duties were interfering with the controller's tower responsibilities during the 28-second critical window just before the accident.

The controller's workload was not excessive, and ample time was available during the Comair flight's taxi and takeoff roll for him to perform all necessary radar tasks while also monitoring the flight's progress on the airport surface. As a result, the Safety Board concludes that, even though the air traffic manager's decision to staff midnight shifts at LEX with one controller was contrary to FAA verbal guidance indicating that two controllers were needed, it cannot be determined if this decision contributed to the circumstances of this accident.

2.6 Other Related Issues

2.6.1 Airport Charts

At the time of the accident, the flight crew had the most recent Jeppesen chart for LEX, which was dated January 2006. This chart showed taxiway A5 and taxiway A north of runway 8/26. However, at the time of the accident, taxiway A5 had been redesignated as taxiway A, and taxiway A north of runway 8/26 had been closed.

The Jeppesen flight safety manager stated that the Jeppesen chart did not reflect information about the LEX runway and taxiway configuration (received from NFDC on June 23, 2006) because of a software error. After the accident, Jeppesen posted a revised chart on its Web site on August 29, 2006, and issued the revised chart on September 8, 2006. This chart showed future taxiway A7 but not taxiway A5 and taxiway A north of runway 8/26 (the taxiway configuration at the completion of the construction project). Jeppesen and FAA officials indicated that it was not unusual during long-term construction projects for airport charts to differ slightly from what was actually present on the airport and for the changes to be included in local NOTAMs.

[223] In a postaccident interview, the LEX air traffic manager stated that he understood the midnight shift staffing guidance but that he thought he had some flexibility to manage the ATCT and its staff as he deemed necessary.

In addition, the August 3, 2006, NACO chart for LEX had been updated by the FAA to show the taxiway configuration at the completion of the construction project (future taxiway A7 was shown but not taxiway A5 and taxiway A north of runway 8/26). The program manager of the LEX construction project at the FAA's Memphis Airports District Office stated that he did not recommend publishing an interim chart because the chart would have been inaccurate during the time both before and after the construction project.

Neither the Jeppesen nor the NACO chart reflected the taxiway identifiers that were present on the airport at the time of the accident. However, the CVR did not record any discussion between the flight crewmembers indicating confusion about the airport taxiways, and the discrepancies between the Jeppesen chart available to the flight crew and the taxiway identifiers on the airport at the time would not have misled the pilots to runway 26 instead of runway 22. Nevertheless, the Safety Board recognizes that, under different circumstances, up-to-date charts might be necessary for a flight crew's successful navigation on an airport and that, for those circumstances, the charts would need to be complete, accurate, and timely. The Safety Board concludes that, because of an ongoing construction project at LEX, the taxiway identifiers represented in the airport chart available to the flight crew were inaccurate, and the information contained in a local NOTAM about the closure of taxiway A was not made available to the crew via ATIS broadcast or the flight release paperwork.

2.6.2 Automatic Terminal Information Service Broadcasts

The flight crew indicated that it had received ATIS information "alpha," and the controller advised the flight crew when ATIS information "bravo" was current. Neither ATIS broadcast indicated that taxiway A north of runway 8/26 had been closed as part of the airport construction project. FAA Order 7110.65, paragraph 2-9-3g, "Content," states that taxiway closures that affect the entrance or exit of active runways should be included in ATIS broadcasts. After the accident, the Safety Board determined that the taxiway closure information had been included in a sampling of ATIS broadcasts recorded between 0530 and 0630 each day between August 20 and 26, 2006.

FAA Order 7110.65, paragraph 2-9-2d, "Operating Procedures," allows controllers to supplement ATIS information during their direct communications with pilots. The CVR showed that the controller did not advise the flight crew about the status of taxiway A north of runway 8/26. Because the construction project affected the entrance and exit paths of runway 4/22, either the ATIS broadcasts or the controller's direct communications with the pilots should have included information about the altered taxiway A configuration.

The Safety Board was not able to determine what effect, if any, information about the closure of taxiway A north of runway 8/26 (either through the ATIS broadcasts or the controller's direct communications with the flight crew) would have had on the circumstances of this accident. However, this possible cue would not have had the same salience as the primary cues—the airport markings and signage—that were accurate

and available to the flight crew. It is also important to note that the airplane turned onto runway 26 before it would have encountered the area on taxiway A that had been closed. Thus, the Safety Board concludes that the controller's failure to ensure that the flight crew was aware of the altered taxiway A configuration was likely not a factor in the crew's inability to navigate to the correct runway. Nevertheless, the Board recognizes that, under different circumstances, information on an altered taxiway configuration might be necessary for a flight crew's successful navigation on an airport and that, for those circumstances, the crew would need to receive complete, accurate, and timely ATIS information.

2.6.3 Local Notice to Airmen

The local NOTAM that indicated that taxiway A north of runway 8/26 was closed was not included in the Comair flight planning system or the flight release paperwork for the accident flight because the company determined that the information in the local NOTAM did not affect safety of flight. The Safety Board was not able to determine what effect, if any, this information would have had on the circumstances of this accident. However, this possible cue would not have had the same salience as the primary cues—the airport markings and signage—that were accurate and available to the flight crew. In addition, the Board's analysis of the accident determined that the taxi to runway 22 was relatively simple and could have been successfully conducted by using the cues and aids available to the flight crew. Thus, the Safety Board concludes that, because the information in the local NOTAM about the altered taxiway A configuration was not needed for the pilots' wayfinding task, the absence of the local NOTAM from the flight release paperwork was not a factor in this accident.

As stated in section 1.18.6, the FAA has planned initiatives to modernize the current NOTAM system. These initiatives include aligning the U.S. NOTAM system with that of ICAO by October 2007 so that U.S. NOTAM information can be processed and provided to flight crews in a more timely, accurate, complete, and traceable manner and having digital NOTAM data displayed in the cockpit in textual and graphical formats. For this accident, even though the information in the local NOTAM was not necessary for the flight crew's successful navigation to the correct runway, such information might be necessary under different circumstances. Thus, the Safety Board is pleased that the FAA is taking a proactive role to improve the current NOTAM system.

2.6.4 Presence of Extended Taxiway Centerline

One of the three centerlines that diverged from the taxiway A hold short position for runway 8/26 led to taxiway A north of runway 8/26, which had been closed and was blocked by low-profile barricades with flashing red lights. This extended taxiway centerline had not been removed at the time of the accident.

The LEX construction plan called for the removal of taxiway A north of runway 8/26 and the associated extended taxiway centerline within 30 to 45 days of that taxiway's closure. Because proper barricades had been put into place until such time, and because the CVR did not record any confusion between the flight crewmembers about the taxiway A configuration, the Safety Board concludes that the presence of the extended taxiway centerline to taxiway A north of runway 8/26 was not a factor in this accident.

3. CONCLUSIONS

3.1 Findings

1. The captain and the first officer were properly certificated and qualified under Federal regulations. There was no evidence of any medical or behavioral conditions that might have adversely affected their performance during the accident flight. Before reporting for the accident flight, the flight crewmembers had rest periods that were longer than those required by Federal regulations and company policy.

2. The accident airplane was properly certified, equipped, and maintained in accordance with Federal regulations. The recovered components showed no evidence of any structural, engine, or system failures.

3. Weather was not a factor in this accident. No restrictions to visibility occurred during the airplane's taxi to the runway and the attempted takeoff. The taxi and the attempted takeoff occurred about 1 hour before sunrise during night visual meteorological conditions and with no illumination from the moon.

4. The captain and the first officer believed that the airplane was on runway 22 when they taxied onto runway 26 and initiated the takeoff roll.

5. The flight crew recognized that something was wrong with the takeoff beyond the point from which the airplane could be stopped on the remaining available runway.

6. Because the accident airplane had taxied onto and taken off from runway 26 without a clearance to do so, this accident was a runway incursion.

7. Adequate cues existed on the airport surface and available resources were present in the cockpit to allow the flight crew to successfully navigate from the air carrier ramp to the runway 22 threshold.

8. The flight crewmembers' nonpertinent conversation during the taxi, which was not in compliance with Federal regulations and company policy, likely contributed to their loss of positional awareness.

9. The flight crewmembers failed to recognize that they were initiating a takeoff on the wrong runway because they did not cross-check and confirm the airplane's position on the runway before takeoff and they were likely influenced by confirmation bias.

10. Even though the flight crewmembers made some errors during their preflight activities and the taxi to the runway, there was insufficient evidence to determine whether fatigue affected their performance.

11. The flight crew's noncompliance with standard operating procedures, including the captain's abbreviated taxi briefing and both pilots' nonpertinent conversation, most likely created an atmosphere in the cockpit that enabled the crew's errors.

12. The controller did not notice that the flight crew had stopped the airplane short of the wrong runway because he did not anticipate any problems with the airplane's taxi to the correct runway and thus was paying more attention to his radar responsibilities than his tower responsibilities.

13. The controller did not detect the flight crew's attempt to take off on the wrong runway because, instead of monitoring the airplane's departure, he performed a lower-priority administrative task that could have waited until he transferred responsibility for the airplane to the next air traffic control facility.

14. The controller was most likely fatigued at the time of the accident, but the extent that fatigue affected his decision not to monitor the airplane's departure could not be determined in part because his routine practices did not consistently include the monitoring of takeoffs.

15. The Federal Aviation Administration's operational policies and procedures at the time of the accident were deficient because they did not promote optimal controller monitoring of aircraft surface operations.

16. The first officer's survival was directly attributable to the prompt arrival of the first responders; their ability to extricate him from the cockpit wreckage; and his rapid transport to the hospital, where he received immediate treatment.

17. The emergency response for this accident was timely and well coordinated.

18. A standard procedure requiring 14 *Code of Federal Regulations* Part 91K, 121, and 135 pilots to confirm and cross-check that their airplane is positioned at the correct runway before crossing the hold short line and initiating a takeoff would help to improve the pilots' positional awareness during surface operations.

19. The implementation of cockpit moving map displays or cockpit runway alerting systems on air carrier aircraft would enhance flight safety by providing pilots with improved positional awareness during surface navigation.

20. Enhanced taxiway centerline markings and surface painted holding position signs provide pilots with additional awareness about the runway and taxiway environment.

21. This accident demonstrates that 14 *Code of Federal Regulations* 91.129(i) might result in mistakes that have catastrophic consequences because the regulation allows an airplane to cross a runway during taxi without a pilot request for a specific clearance to do so.

22. If controllers were required to delay a takeoff clearance until confirming that an airplane has crossed all intersecting runways to a departure runway, the increased monitoring of the flight crew's surface navigation would reduce the likelihood of wrong runway takeoff events.

23. If controllers were to focus on monitoring tasks instead of administrative tasks when aircraft are in the controller's area of operations, the additional monitoring would increase the probability of detecting flight crew errors.

24. Even though the air traffic manager's decision to staff midnight shifts at Blue Grass Airport with one controller was contrary to Federal Aviation Administration verbal guidance indicating that two controllers were needed, it cannot be determined if this decision contributed to the circumstances of this accident.

25. Because of an ongoing construction project at Blue Grass Airport, the taxiway identifiers represented in the airport chart available to the flight crew were inaccurate, and the information contained in a local notice to airmen about the closure of taxiway A was not made available to the crew via automatic terminal information service broadcast or the flight release paperwork.

26. The controller's failure to ensure that the flight crew was aware of the altered taxiway A configuration was likely not a factor in the crew's inability to navigate to the correct runway.

27. Because the information in the local notice to airmen (NOTAM) about the altered taxiway A configuration was not needed for the pilots' wayfinding task, the absence of the local NOTAM from the flight release paperwork was not a factor in this accident.

28. The presence of the extended taxiway centerline to taxiway A north of runway 8/26 was not a factor in this accident.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the flight crewmembers' failure to use available cues and aids to identify the airplane's location on the airport surface during taxi and their failure to cross-check and verify that the airplane was on the correct runway before takeoff. Contributing to the accident were the flight crew's nonpertinent conversation during taxi, which resulted in a loss of positional awareness, and the Federal Aviation Administration's failure to require that all runway crossings be authorized only by specific air traffic control clearances.

4. RECOMMENDATIONS

4.1 New Recommendations

As a result of the investigation of this accident, the National Transportation Safety Board makes the following recommendations:

—To the Federal Aviation Administration:

Require that all 14 *Code of Federal Regulations* Part 91K, 121, and 135 operators establish procedures requiring all crewmembers on the flight deck to positively confirm and cross-check the airplane's location at the assigned departure runway before crossing the hold short line for takeoff. This required guidance should be consistent with the guidance in Advisory Circular 120-74A and Safety Alert for Operators 06013 and 07003. (A-07-44)

Require that all 14 *Code of Federal Regulations* Part 91K, 121, and 135 operators install on their aircraft cockpit moving map displays or an automatic system that alerts pilots when a takeoff is attempted on a taxiway or a runway other than the one intended. (A-07-45)

Require that all airports certificated under 14 *Code of Federal Regulations* Part 139 implement enhanced taxiway centerline markings and surface painted holding position signs at all runway entrances. (A-07-46)

Prohibit the issuance of a takeoff clearance during an airplane's taxi to its departure runway until after the airplane has crossed all intersecting runways. (A-07-47)

Revise Federal Aviation Administration Order 7110.65, "Air Traffic Control," to indicate that controllers should refrain from performing administrative tasks, such as the traffic count, when moving aircraft are in the controller's area of responsibility. (A-07-48)

4.2 Previously Issued Recommendations Reiterated in This Report

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

> Amend 14 *Code of Federal Regulations* (CFR) Section 91.129(i) to require that all runway crossings be authorized only by specific air traffic control clearance, and ensure that U.S. pilots, U.S. personnel assigned to move aircraft, and pilots operating under 14 CFR Part 129 receive adequate notification of the change. (A-00-67)

> Amend Federal Aviation Administration Order 7110.65, "Air Traffic Control," to require that, when aircraft need to cross multiple runways, air traffic controllers issue an explicit crossing instruction for each runway after the previous runway has been crossed. (A-00-68)

4.3 Previously Issued Recommendations Resulting From This Accident Investigation

As a result of the investigation into this accident, the Safety Board issued the following recommendations to the Federal Aviation Administration (FAA) on December 12, 2006:

> Require that all 14 *Code of Federal Regulations* Part 121 operators establish procedures requiring all crewmembers on the flight deck to positively confirm and cross-check the airplane's location at the assigned departure runway before crossing the hold short line for takeoff. (A-06-83)

> Require that all 14 *Code of Federal Regulations* Part 121 operators provide specific guidance to pilots on the runway lighting requirements for takeoff operations at night. (A-06-84)

For additional information about these recommendations, see sections 1.18.3.1 and 2.4.1 of this report.

Also, the Board issued the following recommendations to the FAA on April 10, 2007:

> Work with the National Air Traffic Controllers Association to reduce the potential for controller fatigue by revising controller work-scheduling policies and practices to provide rest periods that are long enough for

> controllers to obtain sufficient restorative sleep and by modifying shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance. (A-07-30)
>
> Develop a fatigue awareness and countermeasures training program for controllers and for personnel who are involved in the scheduling of controllers for operational duty that will address the incidence of fatigue in the controller workforce, causes of fatigue, effects of fatigue on controller performance and safety, and the importance of using personal strategies to minimize fatigue. This training should be provided in a format that promotes retention, and recurrent training should be provided at regular intervals. (A-07-31)
>
> Require all air traffic controllers to complete instructor-led initial and recurrent training in resource management skills that will improve controller judgment, vigilance, and safety awareness. (A-07-34)

For additional information about these recommendations, see section 1.18.3.2 of this report.

In addition, the Board issued the following recommendation to the National Air Traffic Controllers Association on April 10, 2007:

> Work with the Federal Aviation Administration to reduce the potential for controller fatigue by revising controller work-scheduling policies and practices to provide rest periods that are long enough for controllers to obtain sufficient restorative sleep and by modifying shift rotations to minimize disrupted sleep patterns, accumulation of sleep debt, and decreased cognitive performance. (A-07-32)

For additional information about this recommendation, see section 1.18.3.2 of this report.

4.4 Previously Issued Recommendations Classified in This Report

Safety Recommendation A-06-83 is classified "Closed—Acceptable Alternate Action/Superseded," and Safety Recommendation A-06-84 is classified "Open—Acceptable Alternate Response," in section 2.4.1 of this report.

Safety Recommendations A-07-30 and -31 are classified "Open—Acceptable Response" in section 2.2.3.3 of this report.

Safety Recommendation A-07-34 is classified "Open—Acceptable Response" in section 2.2.3.2 of this report.

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Chairman

ROBERT L. SUMWALT
Vice Chairman

DEBORAH A. P. HERSMAN
Member

KATHRYN O. HIGGINS
Member

STEVEN R. CHEALANDER
Member

Adopted: July 26, 2007

Members Hersman and Higgins filed the following concurring statements on August 2, 2007.

BOARD MEMBER STATEMENTS

Member Hersman, Concurring:

It was clear in the Safety Board's deliberation of probable cause of this accident that some of the board members believed it crucial to maintain a sharp focus on the pilots' behavior as the cause of this accident, and that to cite too many other factors in this tragic event would undermine that focus. While I share a desire to emphasize pilot behavior as the chief component of causation in this accident, I also believe that the Safety Board could have taken a broader view of other contributing factors without diminishing attention to the primary cause.

There is no question that commercial air travel in the United States is safer than ever before. The reduction in the number of fatalities and the improved accident rate is not a function of luck or good fortune, but the result of a concerted effort to create a redundant and continuously improving system of safety. Single safety measures cannot ensure safe operations; complex operating systems typical of aviation require a system of safety measures or defenses to protect them from accidents. Comair 5191 was the worst domestic aviation accident in the almost five years. Because major aviation accidents are becoming so rare, the Comair 5191 accident has provided us both the opportunity and the obligation to dig deeper into the contributing factors involved in this tragedy.

NTSB investigations focus not only what caused a crash, but also what should be done to prevent a future crash. While we investigate the people and the machines involved in every accident, it is important that we also study the system in which they operate to pinpoint areas in need of improvement to enhance overall safety. To raise simple imagery, a safety system is like a plastic jug full of water. If the jug has a pinhole (or a latent failure), some of the water leaks out. If the jug has a few pinholes, more water leaks out. If the jug has a lot of pinholes, it becomes a sieve, and it fails to hold water.

The information gathered by our investigators showed that the two pilots of Comair 5191 were competent pilots. In interview after interview, their fellow pilots described them as professionals who followed the rules, "flew by the book." For reasons unknown, they behaved in a too-casual manner during their flight on August 27, 2006, and our probable cause cites their failures that led to this fatal accident. Much of our investigation involved the search for an explanation of why the pilots behaved as they did, but those answers remained elusive. Because we will never know why the pilots failed to observe the cues available to them on that Sunday morning, it becomes even more important for us to explore the elements that enabled them to believe that they were on runway 22 rather than runway 26.

In this accident, the Safety Board found a number of "pinholes" in the safety "water jug" that make up our complex aviation system. There were small leaks in the systems that both the pilots and the air traffic controller were operating in. Not one of these latent failures was significant enough to eclipse the actions of the pilots as the probable cause of

this accident, but viewed as a group, they illuminate safety weaknesses that, if eliminated, may very well prevent another accident like this one.

The system the pilots were operating in had multiple holes. These latent failures included informational, organizational and procedural shortcomings:

- Inaccurate Airport Chart: The airport was under construction, and the charts were not kept current with the rapid changes that were taking place during the construction project. The airport chart provided to the crew did not accurately reflect the taxiway identifiers and the closed taxiway at Blue Grass Airport on August 27, 2006.

  Only after the accident did Jeppesen realize that there was on-going construction at LEX. Due to a previously unrecognized software glitch, any information Jeppesen received after normal work hours on Fridays was not included in their regular updates. Furthermore, Jeppesen modified the Blue Grass Airport chart after the accident to include a note that runway 8/26 is "daytime VMC use only," even though this information had been published in the Airport/Facility Directory since 2001.

- NOTAM missing in dispatch release: While it is critical for flight crews to have accurate charts, it is understandable that these paper charts will be inaccurate at times, especially during construction projects, because they cannot be produced and distributed in a timely manner. The purpose of the local NOTAM system in this situation is to provide a safety redundancy by alerting aviators of the changed surface situation. There was a local NOTAM issued advising that taxiway A north of runway 26 was closed. However, the crew was not given this helpful information in their dispatch paperwork provided by Comair. Furthermore, the information detailing the changes at Blue Grass Airport was buried several pages into the dispatch release, on the bottom of page 10 and the top of page 11, and was shown as follows:

  LEX 4/22 ASDA 7003 TORA 7003 TODA 7003 LDA 6603
  LEX 22 ILS GP OTS WER 0608181330
  LEX 4/22 RCLL OTS
  LEX 4 ALS OTS
  LEX 4 TDZ LGT OTS

  About a week after the accident, Comair began including in the dispatch paperwork a notice to flight crews that airport diagrams may not reflect airport signage and markings and that the Jeppesen chart may not accurately reflect the airport configuration. The notice further advised crews to utilize the high threat taxi procedures at Blue Grass Airport in which both pilots would remain "heads-up" to monitor the taxi and hold short locations. Prior to the accident, the high threat taxi procedures were not considered necessary for flight crews to navigate the changing circumstances at Blue Grass Airport. Comair 5191 proved that assumption to be wrong.

While hindsight is always 20/20, one cannot help but wonder if the outcome of the accident flight would have been different if the crew had received the following information that was provided to the crew of another Part 121 air carrier post-August 27, 2006, on *page 1* of their dispatch release:

-----LEX CAUTION DURING TAXI -----
FLIGHT CREWS SHOULD BE VIGILANT DUE TO THE CONSTRUCTION AND TAXIWAY RENAMING. IF IN DOUBT AS TO TAXI INSTRUCTIONS REQUEST ASSISTANCE FROM LEX GROUND.
THE REVISED JEPPESEN 10-9 AIRPORT DIAGRAM EFFECTIVE 8 SEP 06 SHOWS ALPHA 7 TAXIWAY TO RUNWAY 22. ALPHA 7 TAXIWAY IS CURRENTLY UNDER CONSTRUCTION AND IS BARRICADED. THE 10-9 CHART DOES NOT SHOW ALPHA TAXIWAY BETWEEN RUNWAY 26 AND RUNWAY 22 WHICH IS BEING USED IN THE INTERIM TO ACCESS RUNWAY 22 DEPARTURES. WHEN DEPARTING RUNWAY 22 FROM ALPHA INTERSECTION REQUEST BACK TAXI TO ACHIEVE FULL LENGTH AIRPORT ANALYSIS PERFORMANCE DATA.

- Incomplete ATIS Broadcast: The ATIS broadcast provided by the air traffic controller at LEX was another opportunity for the crew to receive information about the changed taxi route, but this too was a missed opportunity. For no reason that could be identified by our investigators, the controller did not comply with FAA Order 7110.65 that states that taxiway closures that affect the entrance or exit of active runways should be included in the ATIS broadcast. Our investigators found that taxiway closure information was included in the ATIS broadcasts recorded between 0530 and 0630 each day between August 20th and 26th, 2006 – but not on August 27th. A review of the ATIS broadcast on the morning of the accident indicates that controller advised "pilots use caution for construction on air carrier ramp," but there is no information about the closure of taxiway Alpha.

  The chart, the dispatch paperwork, and the ATIS broadcast were three available sources of information for the crew and they all were lacking. Furthermore, there was no redundancy or mechanism to ensure that surface navigation information provided to flight crews was accurate or complete.

- Lack of compliance with standard operating procedures (SOPs): The flight crew failed to perform a full taxi briefing, as called for in the Comair manual, which should have included information about crossing runway 26 to get to runway 22. Had the crew members spoken aloud about the need to cross runway 26 before getting to the hold short line for runway 22, one or both of them may have questioned whether they had in fact crossed a runway when they stopped at runway 26 thinking they were on runway 22. Furthermore, the crew quite comfortably violated their airline's sterile cockpit rule by engaging in non-pertinent conversation after the aircraft was moving under its own power. The Safety Board found that this non-pertinent conversation, more than any other factor, distracted this crew from lining up and taking off from the correct runway.

The fact that this reputable crew violated two basic, critical components of their safety procedures raises the question of how far outside the norm these two pilots were. There was no apprehension about performing an abbreviated taxi briefing or engaging in non-pertinent conversation either before, or after, the airplane was subject to the sterile cockpit requirements. Both pilots seemed relaxed and comfortable continuing their prior conversation during the taxi. Neither acknowledged the sterile cockpit rule nor did their behavior reflect a marked difference in formality. The question to be asked in light of this accident is whether this behavior is "normal" and is likely to be exhibited by other crews. The Safety Board has seen several fatal accidents in the last two years in which crews did not adhere to the standards expected of professional aviators (Crash of Pinnacle Airlines Flight 3701, Jefferson City, Missouri, October 14, 2004; Collision with Trees and Crash Short of Runway, Corporate Airlines Flight 5966, Kirksville, Missouri, October 19, 2004; Controlled Flight Into Terrain, Bamiyan, Afghanistan, November 27, 2004). Because this non-compliant behavior has been exhibited by crews employed by multiple carriers, the questions must be asked, "Is this behavior widespread? Is this a systemic problem?" While it should be noted that this crew's violations may not be as egregious as actions by the other crews mentioned here, the Safety Board determined that their conversation was a contributing factor to this accident, and this accident ultimately resulted in 49 fatalities. If this crew's behavior is not that different than the normal behavior of other crews, then we must question whether they were properly trained, whether the SOPs are effectively enforced, and whether there is a sufficient culture of safety at Comair and other airlines to deter such violations.

- Missing checklist item: The crew of Comair 5191 failed to perform a heading check before beginning their take-off. After two wrong runway take-offs at Houston Hobby in 1989, the NTSB recommended that the FAA ensure that Part 121 and Part 135 operators require their flight crews to cross-check the heading indicator with the runway heading once the aircraft is aligned for take-off. The recommendation was closed in 1990 after the FAA advised the NTSB that almost every airline had incorporated the recommended procedure into their before takeoff checklists. Nevertheless, when the Comair 5191 accident occurred, the procedure was not part of Comair's operations manual, nor was it required to be by FAA (although it is recommended in Advisory Circular 120-74 "Flight Crew Procedures During Taxi Operations").

  We have heard that all pilots are trained to perform this check before take-off and that it is the practice of good pilots to do this; the fact is, we heard the same thing in 1989. We found in the Houston incidents, the pilots indicated that they usually performed a heading check and could not explain why they did not do it on the incident flights. The reason that checklists exist is to ensure that critical safety steps are executed the same way each and every time. The checklist itself is a redundancy, an aid to back stop the standard items executed hundreds of times by an experienced crew. In Comair 5191, this particular omission was perhaps the

single most critical process failure; had the crew been required to cross-check the heading indicator with the runway heading, it would have been clear to them that they were on the wrong runway before they began the take-off.

There were latent failures in the air traffic control system as well, some of which date back months or years prior to the accident:

- Ineffective FAA guidance: The Blue Grass Airport air traffic control tower was staffed in violation of verbal guidance issued by FAA. Following a 2005 loss of separation event in North Carolina while a controller was working both the radar and tower functions, FAA issued verbal guidance indicating that there should be at least two controllers in the tower for all shifts. The guidance was verbal, not written, possibly making it seem less important and allowing for ambiguity and differing interpretations. Additionally, the guidance was not enforced. On November 17, 2006, following the accident, the FAA issued Notice N JO 7210.639 which put into writing the guidance to address staffing requirements for several hundred FAA facilities (of which 138 are combination tower/radar approach facilities similar to Lexington).

- Understaffed Blue Grass Airport air traffic control tower: The tower manager at Blue Grass Airport did not follow the FAA's verbal guidance for staffing the midnight shift, most likely because there were not enough controllers working at the facility to make compliance possible. The tower manager conducted staffing studies in 2005. At least one of the studies was approved by a regional unit and forwarded to FAA headquarters. The study was not acted on by the FAA. In January 2006, the tower manager of the air traffic control tower at Blue Grass requested a staffing increase of two controllers, increasing the staff from 19 controllers to 21 controllers. At the time of the accident, the facility was still staffed with 19 controllers, but ironically, less than a year after the accident, the FAA stated that Blue Grass Airport hired four additional controllers.

  The Safety Board concluded that it could not determine whether staffing the tower with one controller on the midnight shift, rather than two as required by the verbal guidance, would have changed the outcome. However, the fact that the tower staffing was not as it should have been according to the guidance represents one more hole in the jug, one additional leak. The verbal guidance, the understaffing, and the lack of response to the staffing study all indicate management failures. We cannot say with certainty that another set of eyes in the tower would have changed the outcome of Comair 5191, but it could have been another defense against the tragic events of that morning.

- Fatigued air traffic controller: In the 24 hours prior to the accident, the controller had worked almost two complete eight-hour shifts with an eight-hour rest period in between. He reported that he had gotten only about two hours of sleep during that 24-hour period. On the morning of the accident, the controller was likely susceptible to the performance-impairing effects of sleep deprivation and

circadian disharmony. The effects of fatigue can include slowed reaction time, reduced vigilance, and degraded performance of cognitive tasks. The tower scheduling at Blue Grass Airport permitted controllers to work rapidly rotating counterclockwise shifts that violate the scientifically based principles that govern fatigue management, *i.e.* shifts that frequently flipped between day shifts and night shifts on consecutive days and shifts that were separated by minimal rest periods during which controllers were required to rest, eat, and take care of personal and family needs. These difficult and dangerous work schedules are sanctioned by FAA and NATCA and are typical of other towers. The controller's failure to monitor the flight and his inappropriate prioritization of his tasks can possibly be attributed to the impairing effects of fatigue.

- Air traffic controller judgment: The air traffic controller chose to perform the administrative task of performing a traffic count ("counting strips") rather than observe the aircraft take off. The only guidance he was provided for choosing his tasks advised him to choose the task most safety-related. Counting strips is undoubtedly less safety-related than monitoring an aircraft preparing for take-off, yet the controller chose to count strips. Furthermore, the procedures in the tower called for him to perform the traffic count every hour, but he chose to conduct the count for his shift all at once at the end of the shift and while Comair 5191 was taking off.

  The controller admitted that it was not always his practice to monitor an aircraft take-off. According to our report, it took over 30 seconds after the crash for the controller to activate the crash phone, possibly because he had not watched the flight take-off and did not recognize that the explosion and fire were Comair 5191. While monitoring an aircraft cleared for take-off is not a requirement, it is an exercise of good judgment.

  The fact that he did not regularly monitor aircraft under his supervision (and was not required to do so), did not follow the procedures for counting strips hourly, did not broadcast the required information on the ATIS (discussed above), and did not recognize the significance of the guidance for prioritization of his tasks, may indicate that the FAA guidance, training and/or supervision are lacking and that the safety culture in the tower was lax. As with the flight crew, these factors raise the question of how "outside the norm" this controller's behavior was on the morning of the accident.

Many of these issues were discussed during the board meeting and are explored in the report. However, I find it worthwhile to enumerate them in this statement because I believe they should not be completely overshadowed by the simpler conclusion that this accident was caused by pilot error. If we focus only on the actions of the people directly involved in a human factors accident, we will limit ourselves to only cursory improvements. In most of these accidents, the people who made mistakes will not make those same mistakes again, because they have already paid too high a price for their error. Therefore, we should also look at the system in which they were operating, to spot latent

failures that effectively removed the safety net and permitted the crew's active failure to occur unchecked.

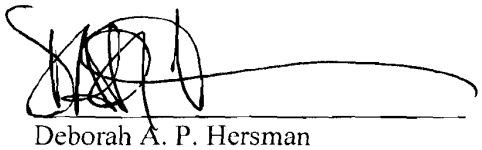
Toward that end, it is important for us to remain mindful of the distinction between NTSB's probable cause and probable cause argued over by lawyers in tort litigation. Our probable cause does not seek to assign blame in terms of legal liability. Rather, our purpose in establishing probable cause in an accident is to designate, as best we can, reasons for the accident so that we can seek ways to address them. Unlike lawyers involved in litigation, we do not necessarily have to prove that a rule was broken or a standard was not followed. Following such a tenet would make it very difficult for the Safety Board to look at broader safety issues and address failures in aviation's system of safety.

The 40-year-old statute authorizing the NTSB requires the Safety Board to designate a probable cause in accident investigations. Much has changed over the years, both in terms of safety advancements and what we have learned through four decades of conducting accident investigations. The fact that after 40 years, the precise meaning of this section of the statute can still be the topic of lengthy debate among staff, as well as among board members, may indicate that the statutory requirement should be revisited.

The 2000 Rand Study of the NTSB entitled, "Safety in the Skies" recommended "the NTSB should move away from simplistic, one-line probable cause statements, and instead consistently adopt a comprehensive statement that reflects the reality that a modern aircraft accident is rarely the result of a single error or failure." Other countries have adopted different approaches to designating causes in an accident. France and the U.K. identify multiple probable causes in their accident investigations. Australia and Canada's accident investigation reports make findings, with different classifications. ICAO's Manual of Aircraft Accident and Incident Investigation (Doc 9756) adopted in 2003, provides guidance for member states, including the United States. With respect to determining causes, the manual states in section 3.2.2.: "Seen together, the causes should present a picture of all of the reasons *why* the accident occurred. The list of causes should include the immediate causes and the deeper or systemic causes… The causes should be formulated with preventative action in mind and linked to appropriate safety recommendations." While I will not postulate here whether one method is better than another, I do suggest that the Safety Board should explore other approaches to determining probable cause or causes as a way to refine our approach and if necessary, ask Congress to grant us the statutory relief needed to structure our probable cause findings to be more comprehensive.

The facts of the Comair 5191 accident will not allow us to ignore the fact that the two pilots taxied to the wrong runway, even though other crews that morning and during the previous week accomplished the same task under similar circumstances. However, it is also significant that other errors by other people and entities ("pinholes" in the system) tended to strip away defenses or safety redundancies that may have prevented this tragedy. We should always endeavor to check, and if necessary improve, pilot judgment and cockpit behavior. But while we do that, we should also endeavor to improve the

shortcomings we find outside of the cockpit so that when a pilot makes a critical error, the safety system is fully capable of catching the mistake and correcting it before it's too late.



Deborah A. P. Hersman

August 2, 2007

Member Kathryn O'Leary Higgins, Concurring:

As we conclude our investigation into this tragic accident, I commend the staff on a thorough investigation and a comprehensive report. My concurring statement is written to highlight two factors that I believe could have broken the chain of events that led to this tragedy: the crew's failure to conduct a full taxi briefing as required by Comair procedures; and the air traffic controller's performance of an administrative task that was not directly related to the safe departure of Comair flight 5191 that morning. Had the flight crew followed their company's procedures or the air traffic controller prioritized safety tasks, the crew's way-finding errors may not have occurred.

The Comair operations manual requires the captain to perform a full "Comair standard" taxi briefing for the first flight the crew flies together before taxi begins, and recommends repetition of the essential elements of taxi clearances, emphasizing runway crossings, during taxi. That briefing could be abbreviated for subsequent flights, but not for the first flight as a crew. The manual sets out specific information that must be included in this briefing, including taxi clearances and runway crossings. A full Comair standard taxi briefing could have helped the crew understand that they had to cross runway 26 before reaching runway 22. This taxi briefing procedure is not widespread among part 121 air carriers, but was included in a September 2005 revision of the Comair operations manual to enhance the safety of airport surface operations and prevent runway incursions.

We note in our report that well-designed flight deck procedures, presumably including a taxi briefing, can be an effective countermeasure against surface operation errors. A full taxi briefing, required for this crew for the first flight of the day and for the first flight as a crew, was intended as just such an effective countermeasure. I believe that the crew's failure to conduct a full taxi briefing, as required by the Comair operations manual, deprived them of an opportunity to navigate to the correct runway by identifying the fact that they would have had to cross runway 26 to get to runway 22. We will never know if a full taxi briefing would have helped the crew avoid the numerous errors made that morning that resulted in taxi to and takeoff from runway 26 instead of runway 22. But, I believe it is our duty to emphasize the critical importance of following standard operating procedures designed to optimize safe aircraft operations to help ensure that future flight crews do not make similar errors.

Our aviation system has redundancy built into it so that there are many safeguards and safety nets to help prevent accidents. Air traffic controllers are a vital part of a system designed to get passengers safely to their destinations, and provide a safety net for flight crews. As one of our air traffic experts said in the Board meeting, air traffic controllers are the last line of defense against crew errors. The air traffic control procedures clearly make safety tasks the first priority of a controller. I continue to believe that that the controller's performance of an administrative task before

Comair 5191 departed was a failure to provide the kind of service and support that is expected in our redundant system. By turning his back on Comair 5191 to count flight strips before the plane was in the air, he missed an opportunity to correct the flight crew's surface navigation errors.

During the Board meeting, both staff and Board members noted that flight crew duties are defined in part by regulation and also by how they are trained. But crews are also expected to exercise good judgment. For example, there were no procedures requiring the Comair pilots to confirm that they were on the correct runway, but the failure to cross check and verify that the airplane was on the correct runway before departure was cited as part of the probable cause for this accident.

I believe the same standard should apply to air traffic controllers. While there may be some debate about whether monitoring aircraft is required by regulation or good judgment, there was no debate that the decision to perform an administrative task before Comair 5191 took off was not a wise choice.

Our aviation system failed Comair 5191 that morning. Two of its most critical components – the flight crew and the air traffic controller – missed opportunities to ensure that the airplane was on the correct runway. I do not dispute the probable cause that was determined for this accident because it states the most likely and primary reason for this accident. The failures of the flight crew and the air traffic controller, however, meet the definition of "contributing factors" articulated at the Board meeting: "other factors that led directly to the cause of the accident;" "secondary reasons that led to the accident;" or "missed or lost opportunities." Therefore, I believe the Board also had an obligation, and an opportunity, to include these failures in the contributing factors to highlight errors that can be corrected and emphasize the judgment needed to ensure the high level of aviation safety we expect in this country.

KATHRYN O'LEARY HIGGINS

August 2, 2007

5. APPENDIXES

APPENDIX A

INVESTIGATION AND HEARING

Investigation

The National Transportation Safety Board was initially notified of this accident on August 27, 2006, about 0645. A go-team departed Washington, D.C., about 1030 and arrived on scene about 1145. Accompanying the team to Lexington was Member Deborah A.P. Hersman.

The following investigative teams were formed: Operations, Human Performance, Structures, Systems, Powerplants, Air Traffic Control, Meteorology, Aircraft Performance, Maintenance Records, Survival Factors, and Witnesses. While the investigative teams were in Lexington, specialists were assigned to conduct the readout of the flight data recorder and transcribe the cockpit voice recorder at the Safety Board's laboratory in Washington, D.C.

Parties to the investigation were the Federal Aviation Administration, Comair, Blue Grass Airport, Air Line Pilots Association, General Electric Aircraft Engines, International Association of Machinists and Aerospace Workers, National Air Traffic Controllers Association, and Teamsters Local 513 (Flight Attendants). In accordance with the provisions of Annex 13 to the Convention on International Civil Aviation, the Transportation Safety Board of Canada (the Safety Board's counterpart agency in Canada) participated in the investigation as the representative of the State of Design and Manufacture. Transport Canada and Bombardier Aerospace participated in the investigation as technical advisors to the Transportation Safety Board of Canada, as provided in Annex 13.

Public Hearing

No public hearing was held for this accident.

APPENDIX B

COCKPIT VOICE RECORDER

The following is the transcript of the Fairchild model A100S cockpit voice recorder, serial number 03035, installed on a Comair CRJ-100, N431CA, which crashed while attempting to take off from the wrong runway on August 27, 2006.

LEGEND

CAM	Cockpit area microphone voice or sound source
HOT	Flight crew audio panel voice or sound source
RDO	Radio transmissions from accident aircraft
PA	Voice transmitted over aircraft public address system
CLR	Radio transmission from the Blue Grass Airport clearance controller
GND	Radio transmission from the Blue Grass Airport ground controller
TWR	Radio transmission from the Blue Grass tower controller
E882	Radio transmission from Eagle flight eight eighty-two
S6819	Radio transmission from Skywest flight sixty-eight nineteen
-1	Voice identified as the Captain
-2	Voice identified as the First Officer
-3	Voice identified as the male Flight Attendant
-4	Voice identified as the aircraft mechanical voice
-5	Voice identified as ACM (additional crew member pilot)
-?	Voice unidentified
*	Unintelligible word
#	Expletive
@	Non-pertinent word
( )	Questionable insertion
[ ]	Editorial insertion

Note 1: Times are expressed in eastern daylight time (EDT).
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: Radio transmissions from CLR, GND and TWR all appear to be the same controller.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:36:07.7 **START of RECORDING** **START of TRANSCRIPT**			
05:36:18.4 **CAM**	[sound of rustling similar to someone entering the cockpit]		
05:36:50.2 **CAM-3**	*** well, I reported at five-thirty *****.		
05:37:26.9 **CAM-1**	***.		
05:37:50.9 **CAM-1**	everything else is good.		
05:37:52.7 **CAM**	[sound similar to crewmember testing oxygen mask]		
05:38:03.4 **HOT-?**	[sound similar to crewmember conducting hot microphone test]		
05:38:04.3 **CAM-1**	circuit breakers, checked, nose wheel steering is off, hydraulic pumps, all off, landing gear lever, down, spoiler lever, lever, retracted, flaps lever, set to flaps twenty, radar, off, AHRS, mag, landing gear manual release, ADG manual release, battery master, on, fire protection, checked, nav lights, on, external ** A/C, no APU, hydraulic pump 3A is on, nosewheel door, closed, aircraft/crew docs, on board, flight compartment safety inspection is complete.		
05:38:28.4 **CAM**	[sound similar to crewmember checking an oxygen mask]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:38:40.9 **HOT**	[three tones similar to CVR test tone]		
05:38:53.0 **CAM-?**	[sound of person whistling]		
05:38:55.7 **CAM**	[sound of hi-lo chime]		
05:39:07.6 **CAM-4**	[sound of chimes similar to fire protection fire test signal] smoke.		
05:39:13.3 **CAM-1**	smoke.		
05:39:20.8 **CAM-4**	[sound of triple chime] bleed air duct.		
05:39:24.9 **CAM-1**	I was talking to another guy I flew with yesterday. he was uh, had put his, bid in for uh, JFK captain. he wasn't real happy about it but.....		
05:39:35.4 **CAM-2**	First Officer?		
05:39:36.3 **CAM-1**	yeah.		
05:39:37.9 **CAM-3**	would you turn the smoking-seatbelt sign on for me?		
05:39:40.2 **CAM**	[sound of chime]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:39:41.0 **CAM-1**	you got it. here come the lights.		
05:39:43.5 **CAM-2**	why wasn't he too happy about it? he can always change it.		
05:39:46.8 **CAM-1**	yeah, you know he just uh, he's just not really looking forward to reserves, that's all. but he feels like you know and I think he's right if he wants to get out of here. that's his decision he wants to do but. he's gotta get that PIC....		
05:40:01.1 **CAM-2**	exactly.		
05:40:01.9 **CAM-1**	...you gotta bite the bullet sometimes but, I mean, nobody wants to do reserve there.		
05:40:08.5 **CAM-2**	nope, not here. not the way they do it. they just they have.....		
05:40:11.0 **CAM**	[sound of chime]		
05:40:12.9 **CAM-2**	...no clue. they don't utilize....		
05:40:14.3 **CAM-?**	it's time.		
05:40:14.4 **CAM-?**	all right.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:40:16.5 **CAM-2**	... the people effectively.		
05:40:17.3 **CAM**	[sound of chime]		
05:40:21.9 **CAM-2**	you know, you're on for six days and you might fly eight hours 'cause they *.		
05:40:27.1 **CAM-1**	it's amazing though right now, they are using everybody pretty efficiently. um, just shows you what they can do. like I mean I don't have more than ten hours in a hotel, any of these days that I've been on....		
05:40:38.2 **CAM-2**	really.		
05:40:38.7 **CAM-1**	...and it's been that way for all month. now September rolls around and I'll guarantee you it'll be a different story.		
05:40:47.4 **CAM**	[sound of chime]		
05:40:50.3 **CAM-2**	because I know Cincinnati base, they have a lot of reserves. but I understand.		
05:40:55.8 **CAM-1**	*.		
05:40:56.0 **CAM-1**	then, they send them all to New York.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:40:57.1 **CAM-2**	right, exactly.		
05:40:58.4 **CAM-1**	yeah.		
05:40:59.9 **CAM**	[sound similar to stick shaker test]		
05:41:04.6 **CAM-4**	glideslope whoop whoop, pull up, wind shear, wind shear, wind shear, terrain, terrain, whoop whoop, pull up. [sound of chime]		
05:41:09.4 **CAM-?**	[sound of person whistling]		
05:41:22.6 **CAM-4**	[sound of triple chime] gear bay overheat.		
05:41:45.7 **CAM-4**	TCAS system tests okay.		
05:41:50.1 **INT-1**	test, test.		
05:41:52.4 **CAM**	[sound of three hi-lo chimes]		
05:42:10.8 **CAM-1**	funny you were talking about @ I mean, I, I, I flew with a guy who was, he said he filled out the application process, he filled out the application and went through the background checks. actually I did my uh, my MV/LOE with him uh, about three or four weeks ago and uh, he was telling me all about it.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:42:33.3 **CAM-2**	well that might do all that stuff prior to actually, giving you, the interview date.		
05:42:38.5 **CAM-1**	uh huh.		
05:42:39.3 **CAM-2**	but you are by no means guaranteed anything....		
05:42:42.2 **CAM-1**	yeah.		
05:42:44.4 **CAM-2**	but.		
05:42:45.1 **CAM-1**	I just talked to my wife about it, we looked at, we looked at it on line. you know and I was looking at the pay scales and uh, yeah I know they provide a place ta, for you to live and things like that and was at four thousand, I don't know, forty-four hundred dollars.		
05:43:01.8 **CAM-2**	fifty-two, fifty-two twelve, a month for the first * month tax free.		
05:43:07.9 **CAM-?**	how is it?		
05:43:08.4 **CAM-2**	yeah.		
05:43:09.4 **CAM-1**	yeah the last time I looked at it or it was like forty-five or something and but. I talked to a guy who was in the military, he said he was, he said it's really pretty for a desert, you know it's....		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:43:22.8 **CAM-2**	yeah well there's a guy, a military guy, up uh, a first officer, in Kennedy, he's like I think you're doing the right thing. he says if not to visit, maybe to be an ex-patriot and live there is not a good thing.		
05:43:40.9 **CAM-1**	yeah, what I heard, you know you can't buy land uum, they'll let you buy a condo, like on a high rise or something, thank you, but you can't buy property.... here they come Kelly.		
05:44:04.9 **CAM-2**	yeah howdy, like yeah, yeah * and then I kept thinking about it.... I guess, when I'm, I'm deciding on making a major decision, if it doesn't feel right in my gut. or if I don't have a little voice, if it's starts talking to me and I'm like I need to re-evaluate.		
05:44:29.5 **CAM-1**	yeah		
05:44:43.2 **CAM-2**	you know it'd be nice to go over there and fly heavy metal, fly international, but they work you hard over there I've been told.		
05:44:50.3 **CAM-1**	oh do they?		
05:44:51.1 **CAM-2**	yeah, they fly you if they can up to a hundred hours ** they have triple sevens *. like for you with the kids, you'd get a housing allowance at a villa. and for me and my wife with no kids, we'd get an apartment. the apartments don't allow any animals and I have four dogs and I'm not, I'm not about to give up, I've had 'em for a while. if I fly overseas, I wanna start and finish here in the States.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:45:32.4 **CAM-1**	yeah.		
05:45:32.9 **CAM-2**	***.		
05:45:36.1 **CAM-1**	you were overseas already. is that what you said?		
05:45:36.9 **CAM-2**	no, if I, if I did fly overseas.		
05:45:38.8 **CAM-1**	ah, okay.		
05:45:44.8 **CAM-1**	emergency equipment, checked, crew oxygen masks, checked left and right, ** psi, CVR, checked, standby instruments, checked, fire protection, checked, gravity cross-flow, checked, duct monitor, checked, hydraulics, auto and on, ice detector, has been checked, cabin signs are on, emergency lights are armed , stall protection system, checked, anti-skid, checked and armed, MLG bay overheat, checked, stab/mach trim, engaged, engine controls, checked, aileron rudder trims checked yaw damper engaged, cabin/exterior checks complete gear and safety pins, have been removed acceptance checklist is complete.		
05:46:19.5 **CAM-2**	*** it just became ** I started looking at it a little more, there was just too many * to get through.		
05:46:30.3 **CAM-1**	you know I....		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:46:31.4 **CAM-2**	is this First Officer single?		
05:46:34.8 **CAM-1**	I don't think so but his, his name is, he's got an Arab uh.		
05:46:40.5 **CAM-2**	oh.		
05:46:42.3 **CAM-1**	he got a, he has some kind of Arab name. @ or something er.		
05:46:50.9 **CAM-1**	he might blend in a little bit but I heard it's like sixty or seventy percent European I mean.		
05:46:55.2 **CAM-2**	well it's not even owned by United Arab Emirates. it's owned by a British company.		
05:47:01.1 **CAM-1**	oh really.		
05:47:08.9 **CAM-2**	yeah but you gotta deal with a lot of Brits and Australians. you know it some of these Brits are a little up tight.		
05:47:34.5 **CAM-2**	if circumstances were different I, I'd consider it, they are as such.		
05:47:46.7 **CAM-2**	plus if I have the opportunity to make Captain.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:47:51.0 **CAM-1**	yeah.		
05:47:55.9 **CAM-2**	I'm gonna talk to my dad to see if maybe he can help me out but I think I'm gonna invest in a seven three type rating. if I make Captain here. I need like three hundred PIC to be eligible to meet their requirements and then I'll....		
05:48:14.1 **CAM-1**	who's that, Southwest? isn't that three thousand PIC?		
05:48:16.7 **CAM-2**	fifteen hundred.		
05:48:18.6 **CAM-1**	fifteen hundred?		
05:48:18.7 **CAM-2**	actually no, thirteen hundred PIC.		
05:48:20.8 **CAM-1**	oh, okay.		
05:48:21.1 **CAM-2**	like thirteen hundred, that's a weird number.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
		05:48:24.4 **ATIS**	Lexington Bluegrass information Alpha, 0854 automated weather. wind one niner zero at eight, visibility eight, few clouds six thousand, sky broken niner thousand. temperature two four, dew point one niner, altimeter three zero zero zero. ILS and visual approaches in use. landing and departing runway two two. runway two two glideslope out of service. pilots use caution for construction on air carrier ramp. hazardous weather information available on HIWAS, Flight Watch or Flight Service frequencies. all departures contact ground control on one two one point niner. advise you have information Alpha.
		05:49:42.2 **RDO-2**	clearance good morning. Comair one ninety one's going to Atlanta with ALPHA.
		05:49:49.3 **CLR**	Comair one ninety one, Lexington clearance. cleared to Atlanta Airport via Bowling Green, ERLIN TWO arrival. maintain six thousand, expect flight level two seven zero one zero minutes after departure. departure's one two zero point seven five. squawk six six four one.
		05:50:06.5 **RDO-2**	okay, got uh, Bowling Green uh, missed the other part. six thousand, twenty point seven five. six six four one.
		05:50:14.1 **CLR**	Comair one ninety one, it's ERLIN TWO, Echo Romeo Lima, India, November Two arrival.
		05:50:20.4 **RDO-2**	'kay ERLIN Two, 'preciate it, Comair one ninety one.
05:50:38.0 **CAM-2**	nothing like **.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:50:41.2 **CAM**	[sound of click]		
05:50:44.6 **CAM-?**	[sound of person whistling]		
05:50:53.7 **CAM-1**	direct Bowling Green, Bowling Green the ERLIN TWO. is that good?		
05:50:58.4 **CAM-2**	any easier than that.		
05:50:59.9 **CAM-1**	[sound of laughter]		
05:51:29.3 **CAM-1**	Chattanooga looks good for the alternate.		
05:51:29.8 **CAM-5**	well, how's it going guys?		
05:51:30.5 **CAM-2**	dude, what's up?		
05:51:32.6 **CAM-5**	how you doin'?		
05:51:33.3 **CAM-1**	hey good, how you doin'?		
05:51:34.8 **CAM-5**	I'm @ with Air Tran trying to get a lift to work this morning.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:51:37.1 **CAM-1**	hey, no problem any seat, * you already got one.		
05:51:38.8 **CAM-5**	there you go.		
05:51:40.0 **CAM-1**	beauty.		
05:51:43.2 **CAM-5**	all right sir.		
05:51:44.4 **CAM-1**	'preciate it.		
05:51:45.1 **CAM-5**	you bet.		
05:51:46.1 **CAM-1**	any time.		
05:51:47.2 **CAM-5**	thanks a lot.		
05:51:47.7 **CAM-1**	can I get the white sheet from you?		
05:51:48.9 **CAM-5**	all right.		
05:51:51.2 **CAM-1**	there you go sir.		
05:51:52.5 **CAM-5**	thanks a lot.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:51:53.8 **CAM-1**	any time.		
05:52:04.3 **CAM-1**	well @ did you bring it in the other day or what's the sequence? keep on with whatever you're doing.		
05:52:09.1 **CAM-2**	it don't matter to me.		
05:52:11.3 **CAM-1**	oh. I'm easy buddy. but, I tell you, I always feel good like I could eat a little more when I get a seatbelt like this man. [sound of laughter]		
05:52:19.6 **CAM-2**	Jesus.		
05:52:22.9 **CAM-2**	*, I'll take us to Atlanta.		
05:52:24.0 **CAM-1**	sure.		
05:52:24.5 **CAM-2**	I looked at, for some weird reason, I don't have that. I have the airport diagram and the arrival and departure plates. I don't have the San Antonio charts.		
05:52:36.3 **CAM-1**	uh, okay.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:52:42.2 **CAM-2**	either I'm just waiting for the stuff to come up from Cincinnati or for now or the secretary there.		
05:52:50.6 **CAM-1**	[sound of chuckle]		
05:52:51.8 **CAM-2**	very capable.		
05:52:52.8 **CAM**	[sound of click]		
05:52:55.2 **CAM-2**	plus we have, we don't have a chief pilot any more.		
05:52:57.9 **CAM-1**	oh, that's right. I heard @ got promoted or something.		
05:53:00.2 **CAM-3**	** passenger's request for an electric cart in the gatehouse for a passenger.		
05:53:03.7 **CAM-1**	@, can I grab another Coke from you?		
05:53:05.2 **CAM-3**	would you like ice?		
05:53:06.1 **CAM-1**	no thanks.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:53:27.2 **CAM-1**	thank you.		
05:53:27.7 **CAM-3**	can I have the PA please so I can do my verification?		
05:53:29.4 **CAM-1**	sure.		
05:53:58.3 **CAM-2**	** three *.		
05:54:12.5 **CAM-2**	sixteen-forty *.		
05:54:20.2 **CAM-?**	[sound of person whistling]		
05:55:04.4 **CAM-2**	I think I have *** this thing I got. my wife called a little excited about it but *** yeah you'd be gone like three or four days at a time, which you know with your wife and kids it might be a little difficult.		
05:55:20.2 **CAM-3**	it's all yours.		
05:55:21.0 **CAM-1**	all right.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:55:24.9 **PA-1**	ladies and gentlemen from the flight deck, like to take this time to welcome you also on board Comair flight fifty one ninety one direct flight to Atlanta. we'll be cruising at uh, twenty-seven thousand feet this morning. and once we do get in the air, it looks like one hour and seven minutes enroute. distance of travel today, we got we got four hundred and twenty two miles. weather conditions Atlanta, * some light winds out of the east, looks like some broken clouds and current temperature of seventy-two degrees Fahrenheit. we'll try to keep it as quiet as possible. hopefully you can catch a nap going into Atlanta. it's our pleasure having you all on board.		
05:56:14.0 **CAM-1**	for our own briefing, Comair standard. run the checklist your leisure. keep me out of trouble. I'll do the same for you. I don't jump on the brakes on your landing. I'll follow along with you. just let me know when you want me to take it. that's it.		
05:56:23.8 **CAM**	[sound of two clicks similar to pilot seat adjustment]		
05:56:25.2 **CAM-2**	I'll do the same whenever you're ready.		
05:56:26.9 **CAM-1**	all right.		
		05:56:27.6 **GND**	information Bravo is now current. the altimeter's three zero zero zero.
05:56:28.0 **CAM-2**	* control ***.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:56:30.4 **CAM-1**	sounds good.		
05:56:34.1 **CAM-2**	right seat flex takeoff procedures off of um.... he said what runway? one of 'em. * two four.		
05:56:43.4 **CAM-1**	it's two two.		
05:56:45.9 **CAM-2**	one ninety at eight		
05:56:49.9 **CAM-2**	two two up to six, white data * FMS, flaps twenty. * smokes or breaks come back here. come into four or two two. on two two the ILS is out. or the glideslope is, the REILS are out. the uh, came in the other night it was like [sound similar to audible exhale] lights are out all over the place.		
05:57:07.8 **CAM-1**	all right.		
05:57:08.4 **CAM-2**	right. remember this runway predicated, before we just go back to Cincinnati.		
05:57:12.9 **CAM-1**	okay.		
05:57:13.7 **CAM-2**	uum, no continuous, anti-ice, weather radar, hand fly 'til about ten. taxi instructions with ATC.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:57:21.7 **CAM-1**	all right.		
05:57:23.3 **CAM-2**	let's take it out and um, take uuuh, Alpha. two two's a short taxi.		
05:57:31.1 **CAM-1**	yeah.		
05:57:35.4 **CAM-2**	any questions?		
05:57:36.5 **CAM-1**	no questions. before starting at your leisure.		
05:57:38.4 **CAM-2**	ACM crew briefing.		
05:57:39.3 **CAM-1**	complete.		
05:57:40.0 **CAM-2**	takeoff brief.		
05:57:40.4 **CAM-1**	complete.		
05:57:40.7 **CAM-2**	radios, NAV aids.		
05:57:42.0 **CAM-1**	uh, six thousand, your side, both in white data, confirmed the flight plan. we got uh, tower, ground twenty one *, is everything on one? do you know?		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:57:49.7 **CAM-2**	no it's not.		
05:57:50.7 **CAM-3**	do you want to do a brief?		
05:57:53.5 **CAM-1**	nothing differed back there that I saw. weather's good Atlanta, scattered to broken clouds. seventy degrees uum, standard chimes, standard calls. if we do have an emergency, I like to open the door and talk face to face.		
05:58:04.5 **CAM-3**	okay.		
05:58:06.0 **CAM-1**	that's about it. anything for me?		
05:58:07.0 **CAM-3**	sounds great.		
05:58:07.9 **CAM-1**	all right.		
05:58:08.4 **CAM-3**	see you in Atlanta.		
05:58:12.2 **CAM-1**	uuh, start engines your leisure.		
05:58:14.8 **CAM-2**	uuuh, ACM crew brief.		
05:58:16.7 **CAM-1**	complete.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:58:17.1 **CAM-2**	takeoff brief		
05:58:18.3 **CAM-1**	hey man, we already did that one.		
05:58:20.5 **CAM-2**	we did?		
05:58:21.0 **CAM-1**	yeah.		
05:58:21.2 **CAM-2**	I'm sorry.		
05:58:22.2 **CAM-?**	[sound of laughter]		
05:58:23.3 **CAM-2**	I'll get it to ya.		
05:58:24.1 **CAM-1**	[sound of laughter]		
05:58:24.6 **CAM-2**	papers, manifest.		
05:58:26.0 **CAM-1**	it's complete out the door.		
05:58:27.2 **CAM-2**	fuel quantity.		
05:58:27.4 **CAM-1**	required to have (seventy), seventy-three.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:58:30.0 **CAM-?**	**.		
05:58:33.3 **CAM**	[sound of several clicks similar to cockpit door operation]		
05:58:35.1 **CAM-2**	V speeds, takeoff data fifty temp. V one, V r is thirty-seven forty-two * forty-five ********. [spoken at a very fast speed] you got normal thrust ** point two.		
05:58:43.5 **CAM-1**	set for flaps twenty.		
05:58:44.5 **CAM-2**	doors.		
05:58:44.9 **CAM-1**	closed.		
05:58:45.3 **CAM-2**	beacon.		
05:58:45.6 **CAM-1**	on.		
05:58:46.0 **CAM-2**	fuel pumps.		
05:58:46.8 **CAM-1**	number one's on.		
05:58:48.7 **CAM-2**	see this is telling me that I really need to do something.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:58:51.7 **CAM-1**	[sound of laughter]		
		05:59:05.7 **RDO-1**	and ground, Comair one ninety one, just a heads-up on the push.
		05:59:11.1 **GND**	Comair one ninety one advise ready to taxi.
		05:59:13.3 **RDO-1**	roger.
		05:59:14.1 **INT-1**	hey, how you doin'? you ca.... can you hear me? okay, brakes released, we're cleared to push sir.
05:59:24.6 **HOT-2**	must be one of us, skinny flight attendant.		
05:59:26.5 **HOT-1**	[sound of laughter]		
		05:59:33.0 **E882**	ground, Eagle flight eight eighty two ready to taxi with Alpha.
05:59:42.0 **HOT-1**	he said it's okay to turn one at your leisure.		
		05:59:43.6 **GND**	Eagle flight eight eighty two taxi to runway two two. altimeter three zero zero zero and the wind's two zero zero seven.
05:59:45.4 **HOT-2**	that's pretty cool the family got to come down.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
05:59:47.2 **HOT-2**	how long of a ride is that?		
05:59:50.9 **HOT-1**	uuuuh. maybe, maybe an hour.		
		05:59:52.9 **E882**	taxi to **, Eagle flight eight eighty two.
05:59:57.5 **HOT-2**	that's cool.		
06:00:09.4 **HOT-1**	both kids were sick though, they, well they all got colds. it was an interesting br, dinner last night.		
06:00:16.1 **HOT-2**	really.		
06:00:16.6 **HOT-1**	huh, oh gosh.		
06:00:19.1 **HOT-2**	how old are they?		
06:00:20.0 **HOT-1**	three months and two years old. who was sneezing, either nose wiped, diaper change I mean that's all we did all night long.		
06:00:31.0 **HOT-2**	oh yeah I'm sure.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
		06:00:32.2 **GND**	** sixteen ninety two thanks, turn right heading two seven zero runway two two, cleared for takeoff.
06:00:32.4 **HOT-2**	[sound of laughter]		
06:00:34.9 **HOT-2**	that's a nice range, age range.		
06:00:37.7 **HOT-1**	yeah, I like two years apart basically and that's the kinda what we were going for.		
06:00:45.3 **HOT-1**	my wife wants four, I, I, I'm, I was good at one.		
06:00:48.5 **HOT-2**	she wants four.		
06:00:49.9 **CAM**	[sound of chime]		
06:00:50.1 **HOT-1**	yeah.		
06:00:50.2 **HOT-1**	[sound of chuckle]		
06:00:52.7 **HOT-2**	it'd be like honey….		
06:01:02.7 **CAM**	[sound of chime]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:01:07.1 **HOT-2**	yeah, it's especially being on reserve it, it's gotta be tough being away.		
06:01:12.2 **HOT-1**	ah, tough on her, oh my God. that's why she came down yesterday. she's like, I just need to get out of this house.		
06:01:18.0 **HOT-2**	yeah, I bet.		
06:01:18.9 **HOT-1**	I'm like I understand. I, I told her, why don't you just spend the night. she said well, if you're gonna get up at oh dark thirty and she said you'll end up waking up the babies. I'm like yeah, you're probably right.		
06:01:32.1 **HOT-2**	yeah it would just be like being at home.		
06:01:35.5 **HOT-1**	yeah, she's like you know, I don't know, she's like I'll....		
06:01:38.5 **HOT-2**	instead of having her rush back and drive....		
06:01:40.6 **HOT-1**	and we got a dog.		
		06:01:40.8 **GND**	*** Lexington tower roger, hold short.
06:01:42.9 **HOT-2**	aah, trust me the dog *. be on the @ slim-fast diet * for a night.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:01:47.4 **HOT-1**	[sound of laughter]		
06:01:48.7 **HOT-2**	uh, parking brake.		
06:01:49.6 **HOT-1**	that's on.		
06:01:50.0 **HOT-2**	number two, actually, engine.		
06:01:51.7 **HOT-1**	one and two are started.		
06:01:52.5 **HOT-2**	starting engines complete.		
06:01:54.3 **HOT-1**	and before taxi.		
06:01:55.6 **HOT-2**	anti-iiiiice.		
06:01:56.6 **HOT-1**	windshields and probes are low and on.		
06:01:58.3 **HOT-2**	nosewheel steering.		
06:01:59.5 **HOT-1**	that's armed.		
06:02:00.0 **HOT-2**	taxi check complete.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
		06:02:01.3 **RDO-2**	Comair one ninety one is ready to taxi we have ALPHA.
		06:02:03.8 **GND**	Comair one ninety one, taxi to runway two two. altimeter three zero zero zero and the winds are two zero zero at eight.
		06:02:08.9 **RDO-2**	three triple zero and taxi two two, Comair one ninety one.
		06:02:12.6 **GND**	Eagle flight runway two two, cleared for takeoff.
06:02:15.1 **HOT-1**	clear left.		
06:02:17.3 **HOT-2**	on the right.		
		06:02:17.9 **GND**	Skywest six eight nineteen radar contact, say altitude leaving.
06:02:18.9 **HOT-1**	flaps twenty, taxi check.		
06:02:21.0 **HOT-2**	full right.		
		06:02:23.8 **GND**	Skywest sixty eight nineteen, climb and maintain one zero thousand, ten thousand, join Victor one seventy one and resume *, own navigation.
06:02:24.0 **HOT-2**	full left.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:02:25.5 **HOT-1**	test your brakes any time.		
06:02:31.1 **HOT-2**	I want to *** down.		
06:02:32.3 **HOT-1**	sure.		
06:02:41.5 **HOT-2**	let's see, comin' back.		
06:02:51.6 **HOT-2**	brakes.		
06:02:52.3 **HOT-1**	they're checked.		
06:02:53.2 **HOT-2**	right, flaps.		
06:02:54.4 **HOT-1**	set twenty, indicating twenty.		
06:02:55.6 **HOT-2**	flight controls.		
06:02:56.3 **HOT-1**	check left.		
06:02:58.3 **HOT-2**	on the right, trims.		
06:02:59.5 **HOT-1**	engage zero seven point two.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:03:02.2 **HOT-2**	radar terrain displays. [spoken in a yawning voice]		
06:03:04.0 **HOT-2**	all the taxi check's complete. [spoken in a yawning voice]		
06:03:12.0 **HOT-1**	finish it up your leisure.		
06:03:16.4 **HOT-2**	yeah, I know three guys at Kennedy. actually two guys uh.... @@ he went but he didn't get past the sim.		
06:03:26.7 **HOT-1**	oh, really.		
06:03:29.1 **HOT-2**	and then um, a First Officer from Cinci....		
		06:03:34.5 **GND**	Eagle flight radar contact, radar contact. say altitude leaving.
06:03:35.1 **HOT-2**	got through the second part....		
06:03:37.2 **HOT-2**	what do you do the uh, these tests.... and he didn't, and that's as far as he got.		
		06:03:40.8 **GND**	Eagle flight eight eighty two, climb and maintain one zero thousand, ten thousand.
06:03:49.3 **HOT-2**	and then @@ he actually got offered the position.		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:03:54.5 **HOT-1**	did he take it or....		
06:03:55.5 **HOT-2**	yeah.		
06:03:56.1 **HOT-1**	ah, okay.		
06:04:01.2 **HOT-2**	second engine started, anti-ice probes windshield low.		
		06:04:03.1 **GND**	* sixteen ninety one, previous question.
06:04:05.6 **HOT-2**	hydraulics checked, APU's on, FMS we got runway two two out of Lexington up to six.		
06:04:13.3 **HOT-2**	thrust reversers are armed, auto crossflow is manual, ignition is off, altimeters three triple zero across the board, crosschecked. I'll be in the back.		
06:04:24.8 **HOT-1**	got one.		
		06:04:25.7 **TWR**	Skywest sixty eight nineteen contact Indy center one two six point three seven.
		06:04:29.6 **S6819**	two six three seven, Skywest sixty eight nineteen.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
		06:04:32.6 **TWR**	Eagle flight eight eighty two, turn right heading two seven zero, join Victor one seventy-one. resume navigation.
		06:04:37.5 **E882**	two seven zero, join victor one seventy one, ****.
06:04:38.2 **PA-2**	and folks one * time from the flight deck, we'd like to welcome you aboard. we're going to be underway momentarily.... sit back relax enjoy the flight. Kelly, when you have a chance, please prepare the cabin.		
06:04:48.2 **CAM**	[sound hi-lo chime similar to cabin/cockpit interphone signal]		
06:04:49.3 **HOT-2**	pre-takeoff * complete cabin report received CAS.		
06:04:53.4 **HOT-1**	checked and clear.		
06:04:54.4 **HOT-?**	**, six seven, **. [whispered]		
06:04:56.6 **HOT-1**	oh.		
06:04:58.1 **HOT-2**	oh yeah.		
06:04:59.4 **HOT-2**	I'm looking at it 'cause like, okay I see seven but it's....		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:05:01.9 **HOT-1**	yeah there's a green extra one there but....		
06:05:06.3 **HOT-2**	uuuh, cabin report's received, CAS clear, ** before takeoff check's complete, ready.		
06:05:12.6 **HOT-1**	all set.		
		06:05:15.1 **RDO-2**	"churliser" [at your leisure spoken very fast] Comair one twenty one ready to go.
		06:05:17.7 **TWR**	Comair one ninety one, Lexington uh, tower, fly runway heading, cleared for takeoff.
06:05:19.2 **HOT-?**	*.		
		06:05:21.0 **RDO-1**	runway heading, cleared for takeoff, one ninety one.
06:05:23.7 **HOT-1**	and line-up check.		
		06:05:25.1 **TWR**	Eagle flight eight eighty two, that heading work for you, do you wanna go uh, northwest around the uh, weather that's ahead of you?
		06:05:30.7 **E882**	no that looks fantastic. thank you very much.

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
		06:05:32.7 **TWR**	* say again please.
		06:05:33.8 **E882**	*** eight eighty two.
06:05:34.4 **HOT-1**	throw that bad boy on.		
		06:05:36.3 **TWR**	Eagle flight eight eighty two, contact Indy center one two six point three seven. good day.
		06:05:39.5 **E882**	twenty six, thirty seven, * eight eighty two.
06:05:41.3 **HOT-2**	transponder's on, packs on, bleeds closed, cleared for takeoff, runway heading. six grand.		
06:05:45.4 **HOT-1**	all right.		
06:05:46.4 **HOT-2**	anti-ice off, lights set, takeoff config's okay, line-up check's complete.		
06:05:51.2 **CAM**	[sound of clicks similar to pilot adjusting his seat]		
06:05:57.6 **HOT-1**	all yours Jim.		
06:05:58.9 **HOT-2**	my brakes, my controls.		

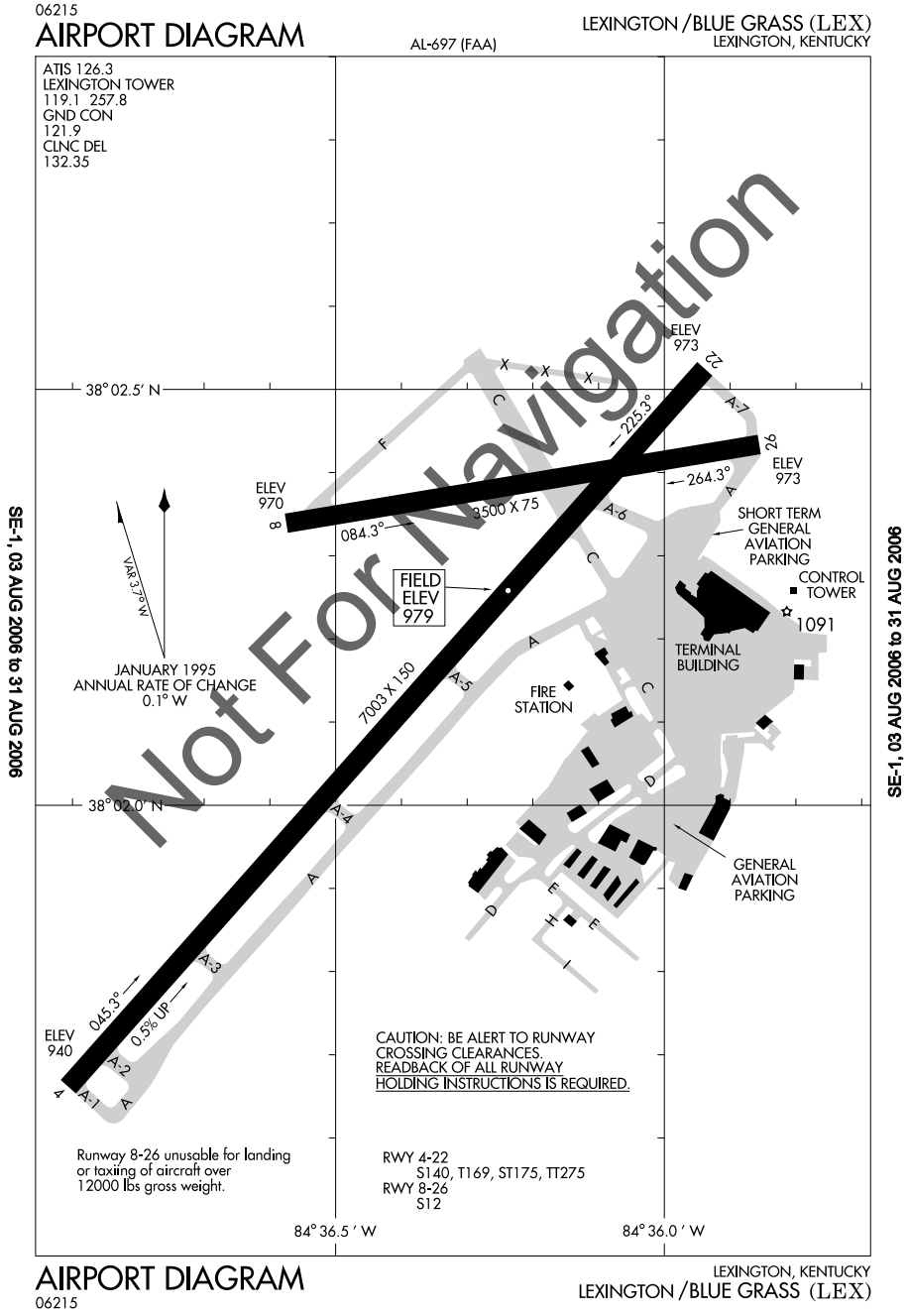
INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:06:05.0 **CAM**	[sound similar to increase in engine RPM]		
06:06:07.8 **HOT-2**	set thrust please.		
06:06:11.7 **HOT-1**	thrust set.		
06:06:16.3 **HOT-2**	dat is weird with no lights.		
06:06:18.0 **HOT-1**	yeah.		
06:06:24.2 **HOT-1**	one hundred knots.		
06:06:25.1 **HOT-2**	checks.		
06:06:31.2 **HOT-1**	V one, rotate.		
06:06:31.8 **HOT-1**	whoa.		
06:06:32.2 **CAM**	[unknown ambient noise]		
06:06:32.6 **HOT-1**	#.		
06:06:33.0 **CAM**	[sound of impact]		

INTRA-COCKPIT COMMUNICATION		AIR-GROUND COMMUNICATION	
TIME (EDT) & SOURCE	**CONTENT**	**TIME (EDT) & SOURCE**	**CONTENT**
06:06:33.3 **HOT-?**	[unintelligible exclamation]		
06:06:33.8 **CAM**	[sound similar to stick shaker]		
06:06:34.7 **CAM**	[sound of chime]		
06:06:34.7 **CAM**	[sound similar to stall warning starts and continues to end of recording]		
06:06:35.1 **HOT-?**	#.		
06:06:35.7 **HOT-1**	[unintelligible exclamation]		
06:06:36.2 **END of RECORDING** **END of TRANSCRIPT**			

APPENDIX C

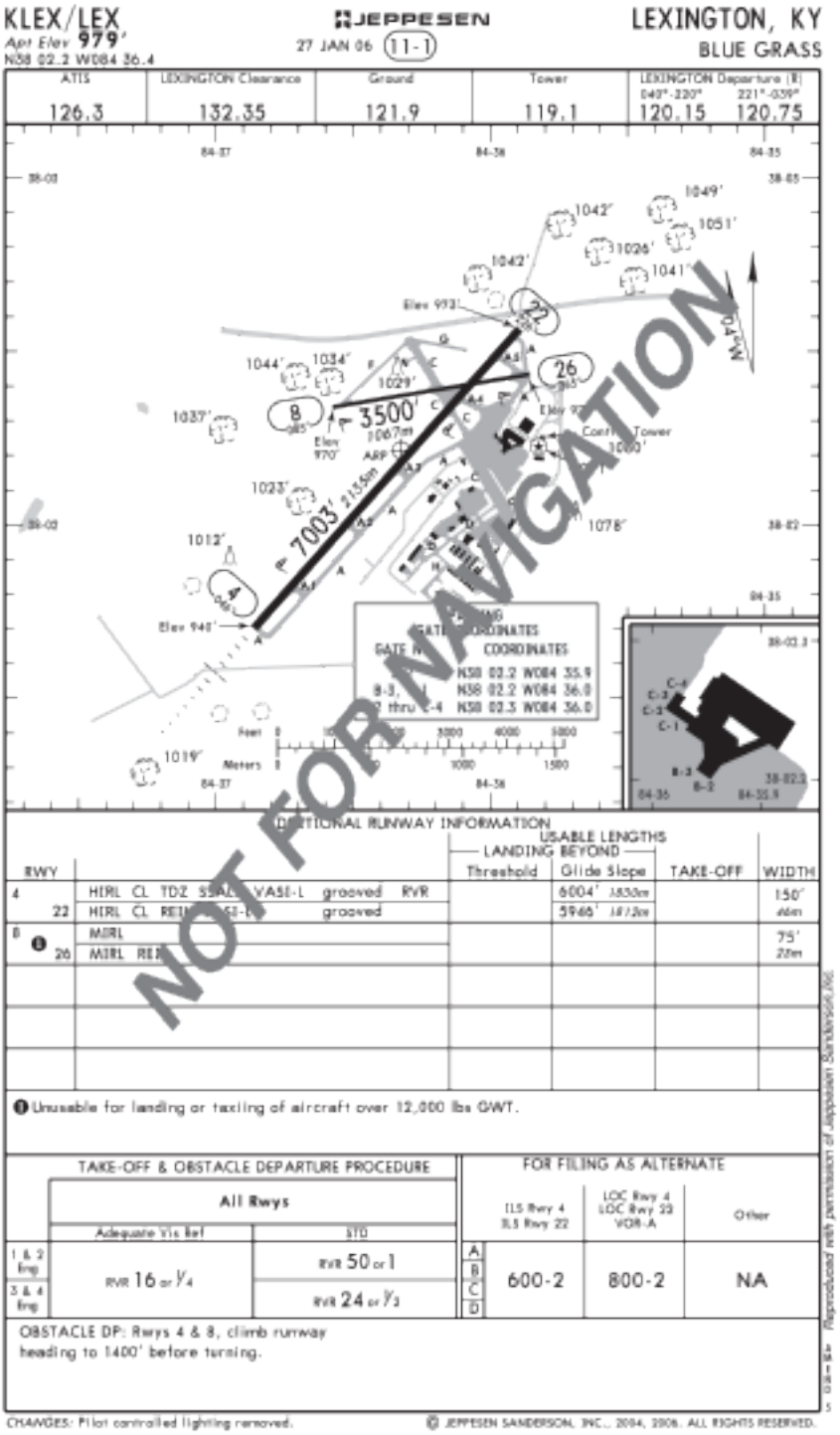
BLUE GRASS AIRPORT CHARTS

National Aeronautical Charting Office chart dated August 3, 2006



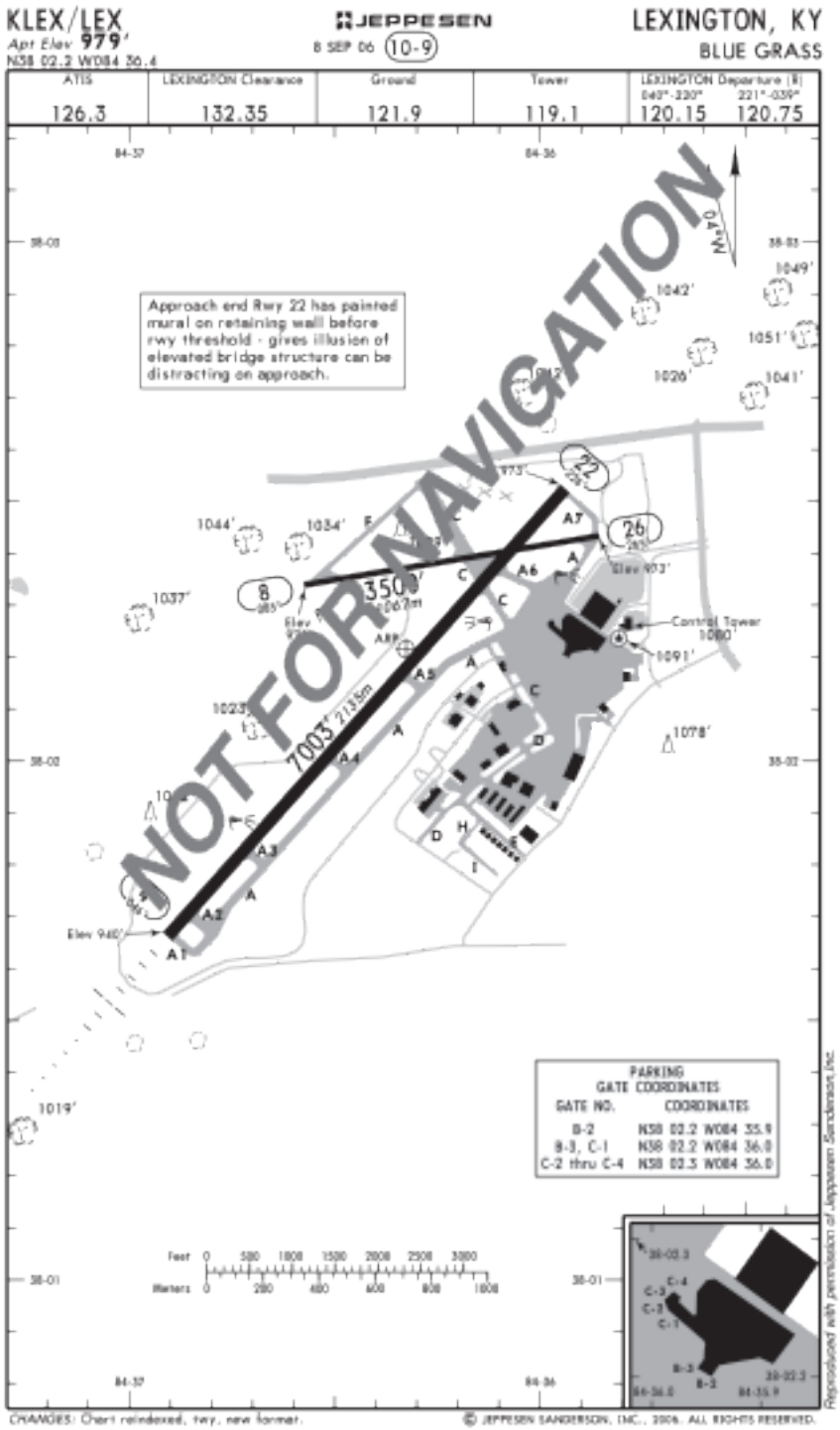
Jeppeson chart dated January 27, 2006

Reprinted with permission by Jeppeson



Jeppeson chart dated September 8, 2006

Reprinted with permission by Jeppeson



this page intentionally left blank