Crash During Takeoff in Icing Conditions
Canadair, Ltd., CL-600-2A12, N873G
Montrose, Colorado
November 28, 2004

Aircraft Accident Brief

NTSB/AAB-06/03

PB2006-108497

National
Transportation
Safety Board
Washington, D.C.

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

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Contents

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Aircraft Accident Brief

Accident Number: DEN05MA029
Operator/Flight Number: Air Castle Corporation, Glo-Air flight 73
Aircraft and Registration: Canadair, Ltd., CL-600-2A12, N873G
Location: Montrose, Colorado
Date: November 28, 2004
Adopted on: May 2, 2006

HISTORY OF FLIGHT

On November 28, 2004, about 0958 mountain standard time,[1] a Canadair, Ltd., CL-600-2A12, N873G, registered to Hop-a-Jet, Inc., and operated by Air Castle Corporation doing business as Global Aviation Glo-Air flight 73, collided with the ground during takeoff at Montrose Regional Airport (MTJ), Montrose, Colorado. The on-demand charter flight was operated under the provisions of 14 *Code of Federal Regulations* (CFR) Part 135 on an instrument flight rules (IFR) flight plan. Instrument meteorological conditions prevailed, and snow was falling. Of the six occupants on board, the captain, the flight attendant, and one passenger were killed, and the first officer and two passengers were seriously injured. The airplane was destroyed by impact forces and postcrash fire. The flight was en route to South Bend Regional Airport (SBN), South Bend, Indiana.

Before the accident flight, the airplane had arrived at MTJ from Van Nuys Airport (VNY), Van Nuys, California, about 0910.[2] Witnesses observed that the airplane had landed on runway 17, taxied to the ramp for fuel, and remained parked on the ramp at the fixed-base operator (FBO) for about 40 to 45 minutes with its auxiliary power unit (APU) running. According to a passenger, one of the pilots remained on board the airplane the entire time.

A pilot-certificated witness who was on the FBO ramp preparing his airplane for flight stated that he saw the accident airplane on the ramp. He stated that there appeared to be snow on the accident airplane's wings, but he could not tell how much. He made a comment about the contamination to his own co-pilot, and his co-pilot remarked to him that both the snow and the airplane's paint scheme were white. The pilot-certificated witness further stated he did not observe either the captain or the first officer conduct a tactile examination of the wing surfaces.

A lineman fueled the accident airplane at its single-point fuel filler port, which is located at the right-wing root, with 400 gallons of Jet A fuel; the fuel was pumped from a fuel truck that

[1] All times are mountain standard time unless otherwise noted.

[2] The same flight crewmembers and passengers who were on board the accident flight were also on the previous flight from VNY. The flight from VNY had five passengers, two of whom got off the airplane at MTJ.

was kept outside and unheated. The lineman stated that he noticed ice on the airplane's nose landing gear area and slush-type ice on the wheels but did not look at the airplane's wings. The lineman stated that, while he fueled the airplane, one of its pilots stood near the wingtip. The lineman noted that the pilot seemed to be looking at the underside of the airplane near the right main landing gear but remained near the wingtip and then walked away when the fueling was completed. The lineman assumed the pilot left to go someplace warm because it was cold and "miserable" on the ramp. The lineman stated that fluffy, wet, snow flurries were falling and that he could see to only about the midfield point of the airport due to reduced visibility.

Personnel in the FBO office and a lineman who was on the ramp deicing other airplanes stated that the accident flight crewmembers did not request deicing services for the airplane and that none were provided. The FBO line service manager observed moderate snow was falling and melting upon contact with the ground.

According to the first officer's legal representative, due to the extent of his injuries, the first officer did not recall any of the circumstances or events regarding the accident flight and was unable to provide any information.

According to the cockpit voice recorder (CVR) transcript, while the airplane was parked on the ramp, at 0942:15, the captain asked the first officer, "how do you see the wings?" The first officer stated, "good," and the captain replied, "looks clear to me."

At 0949:02, during engine start procedures, the first officer asked the captain if he wanted engine bleeds open (on) or closed (off), and the captain replied that he wanted them open.[3] The first officer stated, "yup. Okay so we need to a [sic] eight thousand foot of runway." The captain stated, "so it means [runway] three five."[4]

The first officer announced over the airport's common traffic advisory frequency (CTAF) the crew's intention to taxi the airplane to runway 35. The airport operations manager, who was monitoring the frequency while operating a radio-equipped snowplow on that runway, advised the flight crew over the CTAF that snow removal was in progress on runway 35. The first officer asked how long it would take for the snow removal equipment to exit the runway, and the CVR recorded no reply. He repeated the question, and, again, no reply was recorded.[5]

At 0953:31, the first officer stated, "oh well we gotta get out there anyway," and the captain replied, "well runway three one is here." According to the airport configuration diagram, the airplane was parked on the ramp adjacent to runway 31; the taxi distance from the airplane's parked location to runway 35 was approximately 1 mile.

[3] Various systems in the airplane use engine bleed air, and a pilot can turn certain systems "on" or "off" based on the configuration desired for the takeoff. The airplane's anti-icing system uses 14th-stage engine bleed air that can be selected to flow to the wing leading edges and/or the engine cowl inlets to heat the surfaces to prevent the formation of ice. Other systems, such as the cabin pressurization system, use 10th-stage engine bleed air. The selection of engine bleed air systems reduces the available engine power for takeoff, and, therefore, has an effect on the length of runway required for takeoff (see the Airplane Operations and Airplane Performance sections in this report for more information). The airplane's Federal Aviation Administration-approved Airplane Flight Manual (AFM) contains performance tables that provide takeoff runway length requirements for various engine bleed air system configurations at various airplane gross weights.

[4] Runway 35 was 10,000 feet long; runway 31 was 7,500 feet long.

[5] According to the airport operations manager, he had replied, "momentarily," to the first officer's question.

At 0953:35, the first officer stated to the captain that runway 31 was 7,500 feet long, and the captain asked what length of runway would be needed for takeoff, "…let's say with the bleeds off." The first officer replied, "…that's seventy eight hundred [feet], I think…tenth [stage] closed." The captain asked, "six thousand [feet]?" The first officer replied, "seventy five ninety…seventy eight [hundred feet]."

The captain stated, "well we are between we are forty one thousand [pounds] so." The first officer replied, "sixty eight seventy five so right at seven thousand [feet], I guess. seventy two hundred [feet]?" The captain stated, "okay we can do that….okay. okay we'll go for [runway] three one, then. you agree?" The first officer then stated, "these number [sic] are always conservative anyway."[6]

At 0954:54, the first officer contacted the Denver Air Route Traffic Control Center controller and received the flight's IFR clearance to SBN. The controller instructed the first officer to report back on his frequency after departure, the first officer acknowledged, and the controller received no further radio communication from the flight.

According to the passenger seated on the right side of the cabin, while the airplane taxied for takeoff, slushy clumps of snow and water slid down from the top of the fuselage and across his window. Another passenger stated he noticed water ran off the airplane's skin, "like it had taken a shower."

At 0957:32, the captain stated to the first officer, "you know what lets [sic] have the (engine) cowls[7] and ah do a performance takeoff."[8] At 0958:09, the captain stated, "set power." Ten seconds later, the first officer reported, "eighty knots." At 0958:32, the first officer stated, "there's vee one,"[9] followed by, "rotate." At 0958:39, the first officer asked, "want the gear up?" Immediately thereafter, the CVR recorded the sound of the stickpusher horn[10] and the mechanical voice "bank angle" warning, followed by mechanical voice "five hundred" warning. The recording ended at 0958:46 with the sound of a loud rumble.

The passenger seated on the right side of the cabin stated that the airplane lifted off and climbed to about 20 to 50 feet, then the left wing dropped abruptly and banked to an angle he

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[6] The takeoff runway lengths discussed by the captain and the first officer corresponded with the dry runway (as opposed to a slush- or snow-contaminated runway) performance data contained in the SimuFlite Canadair Challenger Quick Reference Handbook that was on board the airplane. The presence of runway contamination increases the takeoff runway lengths required (see the Airplane Operations section in this report for more information).

[7] Engine cowl inlet anti-ice can be selected independently of the wing leading-edge anti-ice. The AFM contains performance tables that provide takeoff runway length requirements with the engine cowl inlet anti-ice "on." The captain did not discuss these data after making the comment regarding the system.

[8] Generally, to perform a maximum performance takeoff, the pilot aligns the airplane on the runway, holds the brakes, then sets the takeoff power and allows the engines to achieve takeoff thrust before the brakes are released. A maximum performance takeoff enables the airplane to achieve rotation and liftoff within the shortest possible runway distance.

[9] Title 14 CFR 1.2 defines V_1 as the maximum speed in the takeoff at which, in the event of an aborted takeoff, the pilot must take the first action to stop the airplane within the accelerate-stop distance. V_1 also refers to the minimum speed in the takeoff at which, following a failure of the critical engine, the pilot can continue takeoff and achieve the required height above the surface within the takeoff distance.

[10] The sounding of the stickpusher horn is one event in a series of events that occurs as part of the airplane's stall protection system, which is designed to prevent the airplane from entering an aerodynamic stall. See the "Additional Information, Stall Protection System" section in this report for more information.

described as greater than the 7 o'clock position. He indicated that the right wing then dropped to about the 5:30 position, then the left wing dropped again. He stated that he heard a loud thump, his upper body was knocked into the aisle, and he was hanging by the seatbelt. He stated the airplane then fell straight onto its nose. Another passenger, who was seated on the left side of the cabin, estimated that the airplane had climbed to about 20 to 25 feet when the left wing initially "fell" as if "bricks had been dropped" on it, then it "violently slammed back to the right." He stated the left wing then banked back down and struck the ground, and the airplane's nose was down. He stated an explosion of dirt then came through the cabin from the front of the airplane.

One witness, who was west of the airport driving northbound on Highway 50, stated that he saw the airplane off to his right as it rolled on the runway. He indicated that the airplane was headed north but that the nose of the airplane turned sideways toward the right side of the runway and he then saw a flash of flame. He stated that the nose of the airplane faced east perpendicular to the direction of the runway and that the airplane slid along the ground in a northerly direction while smoke and flames came up behind it. Witnesses in a building near the departure end of the runway reported that they heard a loud "boom" and "whooshing" noise and that they looked out the window and saw the airplane on the ground in flames.

PILOT INFORMATION

The Captain

The captain, age 50, held an airline transport pilot (ATP) certificate with a rating for airplane multiengine land and type ratings for Canadair CL-600,[11] Canadair CL-604, Hawker Siddeley HS-125, Cessna CE-500, Cessna CE-650, and Beech BE-300 airplanes. He also held commercial pilot privileges for airplane single-engine land and rotorcraft-helicopter and a type rating for Agusta A-109 helicopters. He held a flight instructor certificate with a rating for airplane single-engine. His most recent Federal Aviation Administration (FAA) first-class airman medical certificate was issued May 25, 2004, with the restriction, "Holder shall possess glasses that correct for near vision while flying." He was hired by Air Castle on May 19, 2004.

According to Air Castle records, the captain had accumulated 12,396 total flight hours, which included 10,851 hours pilot-in-command, 5,644 hours in turbine-powered airplanes, 913 hours in Canadair CL-601[12] airplanes, and 28 hours in Canadair CL-604 airplanes. He had flown 165 hours, 87 hours, and 1.7 hours in the last 90 days, 30 days, and 24 hours, respectively. All of those hours were accumulated in Canadair CL-600-2A12 airplanes.

The captain's most recent Part 135 pilot-in-command competency/proficiency check was accomplished June 7, 2004, in a Canadair CL-601 airplane. Air Castle assigned him as captain of Canadair CL-601 airplanes on July 29, 2004.

A review of entries in the captain's logbook from January 2000 to November 2004 was performed to determine the captain's recent flight experience in winter weather conditions. The review revealed that, during that timeframe, the captain was a flight crewmember on 18 flights in which takeoffs were performed from airports in the northern half of the United States and

[11] With respect to airmen, the CL-600 type rating included Canadair CL-600-2A12 airplanes.

[12] With respect to airplanes, the CL-601 variant included Canadair CL-600-2A12 airplanes.

Canada during the months of November through March. A review of archived weather data for all 18 flights revealed that none of the flights were performed in winter weather conditions similar to the conditions that prevailed for the accident flight.

The First Officer

The first officer, age 30, held an ATP certificate with a rating for airplane multiengine land and a type rating for Hawker Siddeley HS-125 airplanes. He also held commercial pilot privileges for airplane single-engine land. His most recent FAA first-class airman medical certificate was issued April 22, 2004, with the restriction, “Must wear corrective lenses.” He was hired by Air Castle on September 1, 2004.

According to Air Castle records, the first officer had accumulated 1,586 total flight hours, which included 1,300 hours pilot-in-command, 56 hours in turbine-powered airplanes, and 30 hours in Canadair CL-601 airplanes. He had flown 76 hours, 30 hours, and 1.7 hours in the last 90 days, 30 days, and 24 hours, respectively. All of the hours within the last 30 days were accumulated in Canadair CL-600-2A12 airplanes.

The first officer’s most recent Part 135 second-in-command competency/proficiency check was accomplished November 19, 2004, in a flight simulator. Air Castle assigned him as a first officer of Canadair CL-601 airplanes on November 20, 2004.

The first officer’s logbook was not recovered for examination. A review of training and employment records indicated that his training and previous employment experience were in Florida.

Captain and First Officer’s 72-Hour Duty History

The captain and the first officer each resided within the eastern time zone. According to Air Castle records, both the captain and the first officer flew the same schedule from November 23, 2004, until the time of the accident.[13] Although the flight crewmembers’ multiple arrivals and departures occurred in various time zones, all times reported for their 72-hour duty history have been converted to eastern standard time to illustrate the times relative to the time zone in which the captain and the first officer lived.

On November 24, 2004, the captain and the first officer traveled as passengers on a flight from Fort Lauderdale, Florida, which departed about 1600, to Nice, France, and arrived there about 0230 the following morning.[14] They checked into a local hotel for about 20 hours.

On November 26, 2004, about 0130, the captain and the first officer began a trip sequence with a departure from Cote d’Azur Airport (LFMN) in Nice.[15] The flight was en route

[13] According to Air Castle records, the captain went on duty on November 18, 2004, and served each day until the accident as either pilot or as a commercial passenger being repositioned. The captain slept in a different time zone every night from November 18 to November 23, 2004, alternating nightly between the east and west coasts of the United States. The first officer was off duty on November 22, 2004, before he was paired with the captain the next day.

[14] The local time in Nice (central European time) was 6 hours ahead of eastern standard time.

[15] An international relief officer was also on board during this trip sequence to assist in the flying duties.

to Millville Municipal Airport (MIV), Millville, New Jersey, with intermediate stops at Keflavik Airport, Keflavik, Iceland, and Bangor International Airport, Bangor, Maine. They arrived at MIV about 1705, having each accumulated 17 hours 5 minutes of duty time[16] during the three-leg trip. According to Air Castle records, the captain left the airport hangar about 1805 to drive to his local apartment, and the first officer stayed at a local hotel. A review of the captain's cellular telephone records showed multiple calls, either placed or received, from about 1830 to 2058.

According to Air Castle records, a ground transportation vehicle picked up the crewmembers the next morning between 0630 to 0645 at MIV and transported them to Philadelphia, Pennsylvania, to catch a flight on which they traveled as passengers to Los Angeles. They arrived in Los Angeles about 1513.[17] They then traveled by ground transportation to Van Nuys and checked into a local hotel about 1630. The captain's cellular telephone records showed multiple calls from 1514 to 2332.

According to Air Castle records, the next morning, the day of the accident, the captain and the first officer went on duty at VNY at 0830. They departed from VNY in the accident airplane at 0944, and arrived at MTJ at 1110, which was 0910 local time.

The Flight Attendant

The flight attendant, age 36, was hired by Air Castle on November 26, 2004, after having worked for about 1 month as a contract employee. He completed flight attendant ground training on November 10, 2004, and was company-certified for Gulfstream G-1159 airplanes and Canadair CL-600 airplanes. He was formerly a flight attendant with US Airways, Inc.

AIRPLANE INFORMATION

The CL-600-2A12 airplane, serial number (S/N) 3009, was manufactured by Canadair (now Bombardier) in 1983. It was equipped with two General Electric CF34-3A2 turbofan engines (S/N 350485, left; S/N 350486, right), each rated at 8,729 pounds of thrust. The airplane was certificated as a transport-category airplane and was approved for flight into known icing conditions. According to the airplane's weight and balance data sheet, dated February 27, 2002, the airplane was configured with a pilot seat, a copilot seat, a jumpseat, six individual passengers seats, and a couch-style bench with four passenger positions (each position had a seat belt).

The airplane was maintained under an FAA-approved continuous airworthiness program. According to the operator, the most recent inspection, a 100-hour airframe inspection, was accomplished November 26, 2004, at an airframe total time of 14,317 hours and 8,910 landings. Each engine had accumulated 9,087 hours total time, 3,056 hours since overhaul, and 6,072 cycles.

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[16] According to Air Castle company procedures, flight crewmembers were on duty from 1 hour before departure until 30 minutes after arrival.

[17] The local time in Van Nuys (Pacific standard time) was 3 hours behind eastern standard time.

METEOROLOGICAL INFORMATION

MTJ is equipped with an automated surface observing system (ASOS) that automatically records routine aviation weather reports (METARs) and special reports (SPECI).[18] The METAR observations recorded immediately before and after the time of the accident included the following:

> At 0953, reported conditions included calm wind, visibility 1 1/4 miles in light snow and mist, few clouds at 500 feet, ceiling overcast at 900 feet, temperature -1º Celsius (C), and dew point -2º C. Remarks: automated observation system, hourly precipitation less than 0.01 inches (trace), and freezing rain sensor not operating.
>
> At 1004, reported conditions included wind from 340º at 5 knots, visibility 1 mile in light snow and mist, ceiling overcast at 700 feet, temperature -2º C, and dew point -2º C. Remarks: automated observation system, hourly precipitation less than 0.01 inches (trace), and freezing rain sensor not operating.

The surface analysis chart for 1100 depicted a low-pressure system over central Colorado. An occluded front extended from the low in central Colorado to southeast Colorado, where the occluded front split into a cold front. The cold front extended from southeast Colorado to New Mexico and Mexico. Another low-pressure system was located over southeast Colorado and was along a warm front that extended east-southeast from the low-pressure system. MTJ was located on the cold-air side of the occluded front to the west and southwest of the surface low-pressure systems.

The radar mosaic of all regional weather surveillance radars at 0958 depicted several areas of "very light" intensity echoes surrounding MTJ, with reflectivities ranging from 5 to 20 decibels.

An upper air data sounding obtained from an observation site in Grand Junction, Colorado, approximately 45 miles northwest of the accident site, depicted a moist low-level environment with a relative humidity of 75 percent or greater from the surface to 22,000 feet mean sea level (msl).

The National Weather Service (NWS) issued an airmen's meteorological information (AIRMET) Zulu update 2 at 0745, and it was valid until 1400 for a region that included MTJ. The AIRMET indicated occasional moderate rime or mixed icing conditions in clouds and in precipitation from the freezing level, which was identified as from the surface to 8,000 feet msl, up to 24,000 feet msl.

A review of the CVR transcript indicated that, before takeoff, the flight crew listened to the airport's automated weather observation. The CVR recorded that the weather observation included, "light snow, mist…temperature minus zero two celsius, dew point minus zero three celsius."

[18] SPECI reports are issued under certain criteria, which include but are not limited to: wind shift, visibility changes, runway visual range changes, freezing precipitation, and ice pellets. Details and specific issuance criteria can be found in the National Weather Service Federal Meteorological Handbook Number 1.

According to records obtained from the DynCorp direct user access terminal service (DUATS), the captain logged into the system at 0637 and accessed the area forecast and AIRMET information for the flight from VNY to MTJ. He filed a flight plan for that flight, which included an estimated time en route of 1 hour 16 minutes at flight level 330 (33,000 feet pressure altitude). A review of soundings across the region indicated that, at that cruise altitude, the airplane would be exposed to a temperature of about -47º C.

A review of air traffic control transcripts indicated that the captain telephoned the Denver automated flight service station (AFSS) about 0920 to file the IFR flight plan from MTJ to SBN. The Denver AFSS briefer asked the captain if he would like information on "…the latest in adverse conditions for this route of flight or anything else I can get for you or do for you," and the captain replied, "…I have that."

In postaccident interviews, two passengers stated snow was falling while the airplane was parked at MTJ. One of the passengers, who had briefly exited the airplane and walked to the FBO building, stated that his shoes became soaked by what he estimated to be 2 to 2 1/2 inches of slush on the ground. The other passenger estimated there was about 1 inch of slush on the ground.

The airport operations manager stated heavy snow was falling when the airplane landed at MTJ, and snow showers with fog were present at the time it departed.

AIRPORT INFORMATION

MTJ is located about 2 miles west of Montrose at an elevation of 5,759 feet msl. It has two asphalt runways: runway 17-35 is 10,000 feet long and 150 feet wide, and runway 13-31 is 7,500 feet long and 100 feet wide.

According to the airport operations manager, snow removal operations had been in effect at the airport from 0200 to 0700. He stated that, about 0730, snow began to fall again, and a notice to airmen (NOTAM) was issued that stated, "all surfaces 1/4 inch wet snow." He stated that, about 0830, braking action measurements were taken, recorded, and reported to inbound flights, which included the accident flight when it arrived at MTJ that morning. The airport operations manager stated that, after the accident airplane landed, one of the pilots reported that the braking action was "fair."

The airport operations manager stated that snow removal operations on both runways resumed about 0950. He stated that, at the time the accident airplane departed, a snowplow had cleared a 40-foot swath down the center of the runway 31 along its entire length, which left a 3-inch ridge of wet snow along the borders of the cleared area. Outside the cleared area, the runway had about 1/4 inch of snow on its surface.

FLIGHT RECORDERS

The airplane was equipped with a Fairchild A-100 CVR. There was extensive fire damage to the exterior of the unit. The tape inside the unit was intact, and "fair"-to-"excellent"[19]

[19] The National Transportation Safety Board uses the following categories to classify the levels of CVR recording quality: excellent, good, fair, poor, and unusable. An excellent quality recording is one in which virtually

quality analog audio data were preserved on the tape. A CVR group was convened on December 7, 2004, and a transcript was prepared covering the period from 09:41:44 to 09:58:46.[20]

The airplane was not equipped, and was not required to be equipped, with a flight data recorder.[21]

WRECKAGE AND IMPACT INFORMATION

The main wreckage, which included the fuselage, empennage, sections of both wings, and both engines, was at the northwest end of a 1,390-foot debris path that originated off the right side of runway 31. Both engine cowls were consumed by fire, the engine mounts were fire-damaged, and the engines were separated at the damaged mounts.

The initial impact ground scar was observed in the grass off the east side of runway 31; the scar originated 44 feet from the runway's east edge about 636 feet from the north end of the runway (about 6,864 feet from the runway threshold). The ground scar was 5 inches wide and extended 16 feet along a 310º magnetic heading. An impact crater 62 inches long, 20 inches wide, and 10 inches deep was observed about 10 feet 6 inches northwest of the initial impact scar; the east side of the crater was inclined 31º. The debris field, which was 300 feet across at its widest point, continued northwest to the main wreckage.

The outboard 60 inches of the left wing and the left winglet were separated and located within the first 219 feet of the debris field; the left-wing, leading-edge skin was separated along the seams with dirt and grass embedded between the seams. The left aileron quadrant and the nose fuselage radome were also separated and found within the debris field. The nosewheel, the nose landing gear strut, the cockpit windshield and glareshield, the main cabin door and stairs, and the left outboard main landing gear brake assembly and wheel were also separated.

Examination of all flap jackscrew actuator positions (four on the left side and four on the right side) showed the configuration was consistent with a flap setting of 20º. Damage precluded the determination of the pre-crash configuration of the 14th-stage engine bleed air engine cowl inlet anti-ice and wing leading-edge anti-ice systems.

all of the crew conversations can be accurately and easily understood. A fair quality recording is one in which the majority of the crew conversations are intelligible, but cockpit noise or minor electrical or mechanical failure of the CVR may have obscured or distorted portions of the audio information. For additional information on the CVR transcript, see the docket for this accident.

[20] The first 20 minutes of the recording was not transcribed. During this period, the CVR recorded sounds similar to movement and low-level (unintelligible) background conversation, as well as sounds from the radio similar to the captain filing a flight plan, ground-based reports of the snow removal progress on runway 31, and a takeoff announcement from the pilot of another aircraft.

[21] According to 14 CFR 135.152, an approved flight recorder is required for a multiengine, turbine-powered airplane or rotorcraft that has a passenger seating configuration (excluding any required crewmember seat) of 10 to 19 seats, and that was brought onto the U.S. register (or was registered outside the United States and added to the operator's U.S. operations specifications) after October 11, 1991. The accident airplane was U.S.-registered before 1991.

MEDICAL AND PATHOLOGICAL INFORMATION

Autopsies were performed on the captain and the flight attendant by a medical examiner under the authority of the Montrose County Coroner's Office, Montrose Memorial Hospital, Division of Forensic Pathology. The autopsy reports stated the cause of death for the captain and flight attendant was "impact injuries."

Forensic toxicology examination of specimens from the captain, first officer, and flight attendant were performed by the FAA Bioaeronautical Sciences Research Laboratory, Oklahoma City, Oklahoma. For the captain, the report stated that no carbon monoxide or cyanide was detected in the blood and that no ethanol or drugs were detected in the urine. For the first officer, the report stated that lidocaine, an anesthetic, was detected in the blood; the blood sample was taken after medical treatment. For the flight attendant, the report stated that no carbon monoxide or cyanide was detected in the blood and that no ethanol or drugs were detected in the urine. The report stated that diphenhydramine was detected in the liver and that 0.297 (ug/ml, ug/g) diphenhydramine (found in common over-the-counter medications) was detected in the blood.

The Montrose County Coroner determined that the cause of death for the fatally injured passenger was "multiple traumatic injuries."

SURVIVAL ASPECTS

The two surviving passengers stated that neither the pilots nor the flight attendant provided a pretakeoff safety briefing[22] before the accident flight or before the previous flight from VNY to MTJ.

The passenger who was seated on the right side of the cabin in a forward-facing seat stated he had his seatbelt fastened with about 5 or 6 inches of slack. He stated that the passenger who sustained fatal injuries was seated across the aisle from him with his seatbelt fastened.

The passenger who was seated in the left rear forward-facing seat initially stated to investigators in a telephone interview that he had his seatbelt fastened; he subsequently stated that he did not have it fastened. He stated that, when the airplane came to a stop after the crash sequence, he observed a breach in the vicinity of the cabin door. He also observed that the passenger who had been seated on the right side of the cabin was completely buried under cabin debris; he dug that passenger out of the debris and dragged him out of the airplane. He noticed fire had erupted, and he tried to re-enter the cabin to attempt to locate the other passenger but was forced to retreat by the rapidly growing and intense fire. The other passenger's body was later found beneath the wreckage.

[22] According to 14 CFR 135.117, "Briefing of passengers before flight," each pilot in command must ensure before each takeoff that passengers have been orally briefed (either by a qualified person or by an approved recording) on certain safety information, including the requirements for the use of safety belts, the location and operation of doors and emergency exits, the location and operation of fire extinguishers, and other safety information.

TESTS AND RESEARCH

Airplane Operations

The airplane's maximum permitted gross takeoff weight was 44,600 pounds, and the airplane's estimated takeoff weight for the accident flight was 41,600 pounds. The airplane's takeoff center of gravity (CG) was estimated to be 20.6 percent mean aerodynamic chord (MAC). According to the airplane's AFM, the CG limits for the airplane were from 16 to 35 percent MAC.

According to the AFM's Operating Limitations section, "during cold weather operations, the flight crew must ensure that the airplane fuselage, wings and tail surfaces are free from ice, snow or frost." The AFM also stated that, during ground operations, the engine cowl inlet anti-ice and the wing leading-edge anti-ice must be "on" when the outside air temperature is 10º C or lower and visible moisture in any form is present.[23]

The diversion of 14th-stage engine bleed air for the engine cowl inlet anti-ice and the wing leading-edge anti-ice reduces the available engine power for takeoff, and the AFM contained data tables for pilots to use when determining the dry runway takeoff length[24] required with the systems in various configurations. According to the AFM tables, an airplane[25] at 40,000 pounds gross weight with only the engine cowl inlet anti-ice "on" required a dry runway takeoff length of about 7,150 feet. An airplane with the same gross weight with both the engine cowl inlet anti-ice and the wing leading-edge anti-ice "on" required a dry runway takeoff length of about 7,900 feet. The AFM tables indicated that an airplane at 42,000 pounds gross weight with only the engine cowl inlet anti-ice "on" required a dry runway takeoff length of about 8,000 feet and that an airplane with a gross weight of 42,000 pounds and both the engine cowl inlet anti-ice and the wing leading-edge anti-ice "on" required a dry runway takeoff length of about 8,800 feet.

The AFM for the accident airplane did not contain, and was not required to contain,[26] FAA-approved operational planning tables with data for operations on a contaminated runway.[27] According to Air Castle personnel, the accident airplane's AFM contained a section labeled "unapproved supplements"[28] that contained performance-planning tables that were not FAA-

[23] The AFM also stated that, when the airplane is operated on runways, ramps, or taxiways on which surface snow, ice, standing water, or slush is present, the engine cowl inlet anti-ice must be "on" when the outside air temperature is 10º C or lower, and the wing leading edge anti-ice must be "on" when the outside air temperature is 5º C or lower.

[24] For operational planning purposes, takeoff runway length is the greater of the distance required to accelerate to V_1 and then come to a full stop, or the distance required to accelerate to V_1 and then continue acceleration with an engine failed, to rotate, and to climb to a height of 35 feet above the runway surface.

[25] These data are for an airplane configured with the appropriate takeoff flap setting, the appropriate horizontal stabilizer trim setting, CG at 20.6 percent MAC, and 10th-stage engine bleed air "off."

[26] According to 14 CFR 25.1, which prescribes airworthiness standards for the certification of transport-category airplanes, "the landing distance on land must be determined on a level, smooth, dry, hard-surfaced runway." There are no requirements for the determination of landing distances on a wet or contaminated runway.

[27] The presence of runway contamination increases the takeoff runway lengths required due to reduced acceleration during the takeoff ground roll, as well as reduced braking effectiveness during an aborted takeoff.

[28]The supplements were not approved by the FAA, and, according to the AFM, were to have been kept separate from the FAA-approved contents of the AFM. According to the Canadair CL-600-2A12 Airplane Operating

approved (commonly referred to as "blue charts" because they are printed on blue paper) that included data for operations on contaminated runways. According to Air Castle personnel, the company required that pilots obtain performance data for operations on contaminated runways from the blue charts or from the SimuFlite Canadair Challenger Quick Reference Handbook (QRH) that was on board the airplane.[29]

Air Castle did not have, and was not required to have, a specific winter operations manual. Air Castle had an FAA-approved ground deicing and anti-icing program, which was contained in the company's General Operations Manual. According to the General Operations Manual, "No pilot-in-command will take off an aircraft that has frost, ice, or snow adhering to any windshield, wing, stabilizing or control surface…except under the conditions listed in…[14 CFR] 135.227," which states, in part:

> …no pilot may take off an airplane any time conditions are such that frost, ice, or snow may reasonably be expected to adhere to the airplane unless the pilot has completed all applicable training as required by [14 CFR] 135.341 and unless one of the following requirements is met: (1) A pretakeoff contamination check, that has been established by the certificate holder and approved by the Administrator for the specific airplane type, has been completed within 5 minutes prior to beginning takeoff. A pretakeoff contamination check is a check to make sure the wings and control surfaces are free of frost, ice, or snow. (2) The certificate holder has an approved alternative procedure and under that procedure the airplane is determined to be free of frost, ice, or snow. (3) The certificate holder has an approved deicing/anti-icing program that complies with [14 CFR] 121.629(c)[30] of this chapter and the takeoff complies with that program.

Air Castle pilots received instruction regarding winter operations during initial company training via the General Operations Manual and Operations Specifications and during airplane-specific training provided by outside vendors. The training addressed the following: types and characteristics of deicing/anti-icing fluids; the use of holdover times when using deicing/anti-icing fluids; deicing/anti-icing procedures, including inspection and check procedures and responsibilities; surface contamination, critical area identification, and knowledge of how the adherence of frost, ice, or snow adversely affects performance and flight characteristics; cold weather preflight inspection procedures; and techniques for recognizing contamination.

As an on-demand Part 135 operator, Air Castle did not provide, and was not required to provide, a formal crew resource management (CRM) training program. The FAA currently

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Manual, Supplementary Procedures, Section 1, when runway contamination is present, takeoff distance and V1 must be determined with reference to the data shown in the AFM Unapproved Supplement 2, "Operation On Contaminated Runways." Canadair also recommended that pilots should not attempt a takeoff on a runway contaminated with more than 1/4 inch of standing water or slush.

[29] The data in the QRH were also not FAA-approved and, therefore, were kept separate from the approved contents of the AFM. According to these data, an airplane at 40,000 pounds gross weight with the anti-ice systems "on" required a contaminated runway takeoff length of about 10,800 feet. An airplane at 42,000 pounds gross weight with the anti-ice systems "on" required a contaminated runway takeoff length of about 12,100 feet.

[30] Title 14 CFR 121.629 outlines the requirements for an approved ground deicing/anti-icing program, procedures, and training, among other requirements.

requires formal CRM training programs for Part 121 operators only.[31] Air Castle pilots received some CRM training during the company's initial, transition, upgrade, recurrent, and/or qualification training, as well as during airplane-specific training conducted by outside vendors.

Airplane Performance

An airplane performance study[32] was conducted using weather data, runway and ground scar information, the manufacturer's performance models, and elapsed time data obtained from the CVR to calculate the accident airplane's performance and location during key events, such as rotation and liftoff. The calculated performance was then compared with model data that were based upon the takeoff roll for an aerodynamically clean (that is, free of wing surface contamination, such as ice or frost), normally operating airplane with a comparable weight, CG, and flap setting as estimated for the accident airplane, as well as the same elevation, atmospheric conditions, and runway conditions present at the time of the accident.

The study included a model of the airplane's performance with the 14th-stage engine bleed air anti-icing systems "off," as well as with both the engine cowl inlet anti-ice and the wing leading-edge anti-ice "on." Because the diversion of 14th-stage engine bleed air for the anti-ice systems reduces the available engine power for takeoff and the configuration of the bleed air system on the accident airplane could not be determined from the wreckage, the configurations depicted in the study provided upper and lower boundaries for the airplane's performance during takeoff roll.

According to the performance model, the takeoff configuration with the 14th-stage engine bleed air anti-ice systems "off" would require about 3,500 feet of runway to accelerate to V_R (rotation speed) and about 3,900 feet of runway to achieve liftoff. The takeoff configuration with both the engine cowl inlet anti-ice and wing anti-ice "on" would require about 4,000 feet of runway to accelerate to V_R and about 4,500 feet of runway to achieve liftoff. The study results showed that the accident airplane's acceleration and takeoff roll were reasonably correlated to a normal takeoff. In particular, the elapsed estimated timing of the events recorded by the CVR was within the upper and lower boundaries provided by the model's calculated range of performance for the airplane's takeoff roll in both engine bleed air configurations.

The study also correlated the calculated takeoff roll distances with the location of the initial ground scar and concluded that, on the basis of the performance model data, rotation and liftoff of the accident airplane occurred when the airplane was between 3,900 to 4,500 feet from the threshold of runway 31. The CVR recording of the stickpusher horn indicated that the accident airplane reached a high angle of attack (AOA) but did not establish a positive climb rate. The study showed that an aerodynamically clean airplane at a similar calculated airspeed would have begun establishing a positive climb rate after rotation at an AOA lower than that required for activation of the stickshaker or stickpusher.

[31] Between 1980 and 2003, the Safety Board repeatedly recommended that the FAA revise Part 135 to require on-demand charter operators that conduct operations with aircraft requiring two or more pilots to establish an FAA-approved CRM training program for their flight crews in accordance with Part 121, subparts N and O. For more information, see Safety Recommendations A-80-42, A-94-196, A-02-12, and A-03-52, which are available on the Safety Board's Web site at <http://www.ntsb.gov>.

[32] For more information about this study, see the Aircraft Performance Study in the docket for this accident.

Previous airplane accident investigations have shown that large rolling motions are often caused by local separation of airflow on the wing. Local airflow separation, the occurrence of aerodynamic stall before the activation of the stickpusher, and a greater-than-expected stall airspeed are consistent with upper wing surface contamination.[33] The study conducted for this investigation concluded that the accident airplane's performance just before the accident (that is, large roll excursions as reported by the surviving passengers, high AOA accompanied by activation of the stickpusher horn, and failure to establish a positive climb rate) is consistent with upper wing surface contamination.

Effect of Wing Surface Contamination on Airplane Performance

Previous Safety Board investigations of takeoff accidents involving airplanes with contaminated upper wing surfaces[34] have found that the presence of a small amount of surface roughness on the upper wing surface can reduce maximum lift by as much as 33 percent, depending upon the extent and level of roughness. Wind tunnel and flight-testing by the accident airplane manufacturer indicated that the presence of surface roughness equivalent to 40-grit sandpaper on a CL-600-2A12-type wing can reduce the stall AOA up to 7º compared to the stall AOA of an uncontaminated wing. Once localized airflow separation begins on a portion of a contaminated wing, that wing can stall before the other one, which results in lift asymmetry and large roll rates that are not responsive to control inputs.

ORGANIZATIONAL AND MANAGEMENT INFORMATION

Air Taxi Organization

Air Castle Corporation was founded in 1990, and its corporate headquarters were located in Millville. It was one of several companies that were part of the Winfair Aviation Group, headquartered in Delaware. Air Castle held a Part 135 operating certificate issued September 23, 2003, and was authorized to perform on-demand operations with Gulfstream G-1159A airplanes and CL-600-2A12 airplanes under the business names of California Airways, Global Airways, and Global Aviation. Air Castle leased the accident airplane from Hop-a-Jet.

Airworthiness Directives

On February 8, 2005, Transport Canada issued Airworthiness Directive (AD) CF-2005-03, applicable to Bombardier model CL-600-1A11 (600), -2A12 (601 variant), and -2B16 (601-3A, 601-3R, and 604 variants) airplanes; the FAA issued AD 2005-04-07, applicable to the same airplane models, on February 17, 2005. Both ADs require that the AFM be revised to include a

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[33] Upper wing contamination refers to contamination that accumulates generally on the entire upper surfaces of the wing; such contamination is usually accumulated while the airplane is on the ground. In contrast, wing leading-edge contamination typically accretes while the airplane is in flight.

[34] See a) National Transportation Safety Board, *Takeoff Stall in Icing Conditions, USAir flight 405, Fokker F-28, N485US, LaGuardia Airport, Flushing, New York, March 22, 1992*, Aircraft Accident Report NTSB/AAR-93/02 (Washington, DC: NTSB, 1993), and b) National Transportation Safety Board, *Loss of Control on Takeoff, Cleveland-Hopkins International Airport, Cleveland, Ohio, February 17, 1991*, Aircraft Accident Report NTSB/AAR91-09 (Washington, DC: NTSB, 1991).

new cold-weather operations limitation. AD 2005-04-07 states, "Even small amounts of frost, ice, snow, or slush on the wing surfaces can cause an adverse change in the stall speeds, stall characteristics, and the protection provided by the stall protection system. We are issuing this AD to prevent possible loss of control on takeoff resulting from even small amounts of frost, ice, snow, or slush on the wing leading edges or forward upper wing surfaces."[35] The ADs also require compliance with temporary revisions to the airplanes' AFMs, which specify that, "in addition to a visual check, a tactile check must be done to determine that the wing is free from frost, ice, snow, or slush."

Additionally, in October 2005, Bombardier Aerospace developed an airplane icing awareness program, titled "Icing Awareness, Preflight Considerations," and distributed copies of it to operators of Bombardier regional jets and business jets. The topics covered by the program included low-speed aerodynamics, effects of contamination, contamination formation, and contamination removal and protection.

ADDITIONAL INFORMATION

Supercritical Wing

The **accident** airplane's wing design uses what is known as a supercritical airfoil, which is designed to reduce drag at the airplane's cruise airspeed. This airfoil design, when contrasted with more conventional airfoils, is characterized by a larger leading-edge radius, reduced upper-surface camber, and a concavity in the lower aft surface. These features provide a reduced drag at high airspeeds, yet the airfoil behaves much like a conventional airfoil at lower airspeeds. At lower airspeeds, the pressure distribution on the upper surface of the wing is peaked near the leading edge, and this peak increases with increasing AOA. As the AOA increases beyond the natural stall AOA, the pressure gradient in the leading-edge region reaches a critical value, and flow separation initiates. Depending on the spanwise location of the separation onset, the region of separated flow can grow rapidly to adjacent spanwise locations, eventually stalling the entire wing and resulting in a large drop in lift and an increase in drag.

According to the manufacturer, during natural aerodynamic stall of the CL-600-2A12 airplane, one wing typically stalls before the other once the natural stall angle of attack is exceeded, resulting in asymmetrical lift. Large roll rates and roll angles can then develop, depending upon pilot action.

Previous CL-600-2B16 Accident

The Air Accidents Investigation Branch (AAIB) of the United Kingdom investigated the January 4, 2002[36] crash of an FDR- and CVR-equipped Bombardier CL-600-2B16 at Birmingham Airport. The investigation showed that the airplane's takeoff roll was normal up to

[35] At the time this accident occurred, these ADs were already under development in response to a January 4, 2002, accident in Birmingham, England, involving a Canadair CL-604. The information contained in the ADs was a reiteration and expansion of the information already available to the **accident** flight crew in the AFM.

[36] For more information, see AAIB Aircraft Accident Report No: 5/2004 (EW/C2002/1/2), which is available on the AAIB Web site at <http://www.aaib.dft.gov.uk/cms_resources/dft_avsafety_pdf_030576.pdf>.

the time of liftoff. Immediately after liftoff, however, the airplane rolled to the left despite full-right-aileron and right-rudder application by the flight crew. Within 3.5 seconds after liftoff, the bank angle aural warning and the stickshaker activated, and the airplane struck the ground about 5.5 seconds after liftoff at a bank angle of 111º left-wing down and a pitch angle of 13º airplane-nose down. The AAIB investigation concluded the following:

The roll had resulted from the left wing stalling at an abnormally low angle of attack due to flow disturbance resulting from frost contamination of the wing. A relatively small degree of wing surface roughness had a major adverse effect on the wing stall characteristics and the stall protection system was ineffective in this situation.

Stall Protection System

The natural aerodynamic stall characteristics of the CL-600-2A12 airplane do not inherently meet the airworthiness standards specified under 14 CFR 25.203, "Stall characteristics;" the airplane achieves its airworthiness compliance for stall characteristics under the provisions of 14 CFR 25.21, which allow for "a stability augmentation system or another automatic or power-operated system" to be used.

To prevent the airplane from entering a natural aerodynamic stall, the CL-600-2A12 airplane was equipped with a stall protection system that uses AOA sensor vanes that activate the system at an AOA lower than that at which a natural aerodynamic stall occurs. In the event that the airplane achieves an AOA sufficient to activate the system, the system responds with a series of progressive reactions. For example, as the AOA increases, the system first responds by activating the engine autoignition, then it activates the artificial stall identification (stickshaker), and, lastly, it engages the stickpusher (concurrent with the stickpusher horn) to decrease the airplane's AOA and prevent the onset of stall. Because the stickpusher is designed to activate before a stall condition can develop, it is described as a pre-stall pusher.

According to system design information from the manufacturer, stall protection system activation angles are a function of the flap setting and altitude.[37] For the accident aircraft flaps setting of 20º and the elevation at MTJ, the stickshaker activation occurs when either of the AOA sensor vanes reaches 20º, the stall horn and "STALL PUSH" warning lights in the cockpit activate when either of the AOA sensor vanes reaches 24º, and the stickpusher activates when both sensor vanes exceed 24º.

Anti-Icing Systems

According to the accident airplane's AFM, the airplane was equipped with thermal and electrical anti-icing systems. The electrical anti-icing system was installed for the windshields and various air data system sensors, including the stall protection system AOA sensor vanes. The thermal anti-icing system, which uses 14th-stage engine bleed air, was installed for the wing leading edges and the engine cowl inlets. The wing leading-edge anti-ice and the engine cowl inlet anti-ice could be operated independently of each other, and either or both could be turned

[37] Stall protection system activation angles are not changed when the ice protection system for the engine cowl inlets or wing leading edges are in use.

"off." In the "normal" mode, the wing leading-edge anti-ice functions automatically by monitoring the temperature of the wing leading edges and controlling the flow of 14th-stage engine bleed air to heat the leading edges to prevent the formation of ice.

Wet Wing Fuel Tank Design

Conforming to a wet wing design concept, the airplane's entire wing box structure was sealed to form three fuel tanks: the left and right main tanks and the primary auxiliary tank. The left and right main tanks were formed by the wing box structure outboard of the wing root area. Thus, if the main tanks were filled to maximum capacity, the fuel would come in contact with the sealed upper wing skin area. According to the AFM, "takeoff with more than 500 pounds of fuel in the auxiliary tank is permitted, provided that both wing tanks are full."

ANALYSIS

During takeoff from MTJ in snowing conditions, the Canadair CL-600-2A12 airplane climbed to about 20 to 50 feet, banked abruptly to the left, right, and finally to the left; the left wingtip then collided with the ground followed by the fuselage. The airplane slid along the ground for about 1,390 feet, and a postcrash fire ensued. The on-demand charter flight was operated under Part 135 with an IFR flight plan filed.

According to witnesses, the airplane was parked on the ramp in snowing conditions for about 40 to 45 minutes before taxiing for takeoff. Weather observations for that period of time indicated “wet snow,” or snow with high moisture content, and temperatures between freezing and -2º C. A pilot-certificated witness on the ramp observed contamination on the airplane’s wing surfaces while it was parked on the ramp, but he was uncertain of the extent of the contamination. The witness stated that he did not observe either the captain or the first officer conduct a tactile examination of the wing surfaces. FBO personnel reported that the flight crewmembers did not request ground deicing services and that none were provided.

The CVR recorded that, before engine start, the captain asked the first officer, “how do you see the wings?” The first officer stated, “good,” and the captain replied, “looks clear to me.” The airplane’s takeoff roll did not begin until about 16 minutes later. According to 14 CFR 135.227, a pretakeoff contamination check must be completed within 5 minutes before takeoff any time conditions are such that contamination may reasonably be expected to adhere to the airplane. While the airplane was being taxied for takeoff, a passenger on board observed that slushy clumps of snow and water slid down from the top of the fuselage and across his window.

For an airplane to lift off and transition to a positive climb angle, its flight controls must be configured for takeoff, it must achieve sufficient airspeed during the ground roll, and it must pitch up to a sufficient angle to allow the wings to achieve an acceptable AOA. In addition, the wings must be free of contamination to generate the expected lift at the appropriate airspeed and AOA.

The investigation found that the airplane was configured with the flaps in the takeoff position. An airplane performance study conducted using weather data, runway and ground scar information, the airplane manufacturer’s performance models, and elapsed estimated time data obtained from the CVR showed that the accident airplane’s performance and acceleration during the takeoff roll were normal and that rotation and liftoff occurred about the expected elapsed time and airspeed. The accident airplane’s performance after liftoff, however, was severely impaired. Although the airplane achieved the appropriate liftoff airspeed, pitched up, and lifted off the runway, it was airborne only 8 to 9 seconds and did not transition to a climb. The study showed that an aerodynamically clean airplane at the same airspeed and liftoff would have transitioned to a positive climb. The accident airplane instead remained near the ground and rolled abruptly several times before it collided with the ground.

There was no indication that the flight crew noticed any abnormal airplane performance before it failed to establish a positive climb. About 4 seconds after the airplane’s estimated liftoff, the CVR recorded the first officer ask the captain if he wanted the landing gear raised, which indicates that the airplane had lifted off and that the first officer expected it would transition to a normal climb. Within 1/2 second of the first officer’s question, however, the airplane’s stickpusher horn activated, indicating that the airplane had achieved a sufficiently high AOA to activate the stall protection system sequence. Under normal circumstances (that is, with an aerodynamically clean wing) and at the airspeed the accident airplane achieved, it should have begun generating excess lift and accelerating into a climb at an AOA lower than that required for activation of the stickshaker or stickpusher.

Within 1 second of the stickpusher horn (about 5 seconds after the estimated liftoff), the CVR recorded a "bank angle" (mechanical voice) warning, which indicated that the bank angle had exceeded 17º. Within a period of only 3.5 seconds, the airplane rolled abruptly left, right, and left, consistent with the passengers' statements, and the crash occurred within only 3.7 seconds of the "bank angle" warning.

Safety Board findings during previous airplane accident investigations[38] have shown that large rolling motions are often caused by local separation of airflow from the wing due to upper wing surface contamination, and the AAIB noted similar findings during its investigation of an accident involving an FDR-equipped CL-600-2B16, which crashed in January 2002 as result of wing contamination. Wind tunnel and flight testing conducted by the manufacturer indicated that the presence of wing surface roughness equivalent to 40-grit sandpaper can reduce the stall AOA up to 7º compared to the stall AOA of an uncontaminated wing. Once localized airflow separation begins on a portion of a contaminated wing, that wing can stall before the other one, which results in lift asymmetry and large roll rates that are not responsive to control inputs.

The airplane's large roll excursions and its achievement of an AOA high enough to activate the stickpusher horn without establishing a positive climb rate, even though the airspeed was appropriate, are consistent with local separation of airflow from the wing due to upper wing surface contamination. The Safety Board concludes that the accident airplane failed to establish a positive rate of climb shortly after liftoff and began to roll because of localized airflow separation on the wing due to upper wing surface contamination.

The presence of upper wing surface contamination is likely because the airplane was parked on the ground for about 40 to 45 minutes during freezing precipitation and it was not deiced. A witness observation of upper wing surface contamination while the airplane was parked, as well as a passenger's observation of slush sliding from the top of the fuselage before takeoff, further confirm the presence of contamination. This type of contamination can easily accumulate while an airplane is parked and exposed to freezing precipitation and it accumulates on upper surface areas that cannot be protected by the wing leading-edge anti-ice system (ice on the wing leading edge, which the anti-ice system is designed to prevent, typically accumulates during flight in icing conditions).

Additionally, the airplane had arrived at MTJ after having flown about 1 hour at flight level 330 (where temperatures were about -47º C) and 400 gallons of cold Jet A fuel were subsequently added to the airplane's main fuel tanks (which were of the wet-wing design). As a result, precipitation that may have come in contact with the upper wing skin would have a strong tendency to freeze because the main tanks were filled to capacity with fuel that was no warmer

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[38] See a) National Transportation Safety Board, *Takeoff Stall in Icing Conditions, USAir flight 405, Fokker F-28, N485US, LaGuardia Airport, Flushing, New York, March 22, 1992*, Aircraft Accident Report NTSB/AAR-93/02 (Washington, DC: NTSB, 1993), and b) National Transportation Safety Board, *Loss of Control on Takeoff, Cleveland-Hopkins International Airport, Cleveland, Ohio, February 17, 1991*, Aircraft Accident Report NTSB/AAR-91/09 (Washington, DC: NTSB, 1991).

than the outside air temperature of -3º to -1º C. The upper wing skin area that forms the top of the main fuel tanks is not within the wing area protected by wing leading-edge anti-ice because ice would not typically form there in flight. Moreover, ice accumulation in this area would likely have been difficult to visually detect from the cockpit because the airplane's wing paint color was white.

Following the accident, the Safety Board published a safety alert[39] that summarized the Board's previous findings regarding the hazards of even "almost visually imperceptible amounts" of upper wing surface contamination. In addition, shortly after the accident, Transport Canada issued AD CF-2005-03, applicable to Bombardier model CL-600-1A11 (600), -2A12 (601 variant), and -2B16 (601-3A, 601-3R, and 604 variants) airplanes, and the FAA issued AD 2005-04-07, applicable to the same airplane models, to revise the AFMs to include requirements for visual and tactile inspections of the upper wing surfaces to identify potential contamination during certain cold weather operations.[40] Additionally, in October 2005, Bombardier Aerospace developed and distributed copies of a DVD-based icing awareness program, titled "Icing Awareness, Preflight Considerations," that it distributed to operators of Bombardier regional jets and business jets.

Although it is evident that the upper wing surface contamination accumulated while the airplane was on the ground at MTJ, it is also reasonable to conclude that, on the basis of the passenger and witness statements, the flight crewmembers would have seen the contamination if they had carefully visually examined the airplane's upper wing surfaces. Regardless, the ADs issued by Transport Canada and the FAA that require the tactile inspection of the upper wing surfaces for almost imperceptible amounts of ice are appropriate because the tactile requirement in particular may reinforce the seriousness of upper wing surface contamination. The Safety Board concludes that, had the flight crewmembers conducted a visual and tactile examination of the wings, they likely would have detected accumulated contamination.

The flight crew also failed to recognize the presence of runway contamination as a consideration in determining the runway length required for takeoff. As recorded by the CVR, the captain initially planned to take off from runway 35, which is 10,000 feet long, but a snowplow was operating on that runway, and he did not know how long it would take for it to finish. He instead elected to depart from runway 31, which is 7,500 feet long and adjacent to the ramp where the airplane was parked (the taxi distance to runway 35 was about 1 mile).

The captain's pretakeoff discussions with the first officer indicated that they consulted the performance planning tables for dry runway conditions only. Although it was not determined whether the airplane's anti-icing systems were "on" or "off, " the CVR indicates that the captain initially chose to turn the systems "off" because the use of anti-ice systems reduces the available engine power for takeoff, thus increasing the runway length required for takeoff. The captain's decision to take off from runway 31 was inappropriate because, according to the AFM, the prevailing weather conditions required that the systems be turned "on" and the corresponding runway 31 length was less than required by the AFM for even a noncontaminated runway. The presence of runway contamination increases the takeoff runway lengths required due to the

[39] The safety alert is available on the Safety Board's Web site at <http://www.ntsb.gov/alerts/SA_006.pdf>.

[40] At the time this accident occurred, these ADs were under already under development in response to the January 4, 2002, accident in Birmingham, England, involving a Canadair CL-604. The information contained in the ADs was a reiteration and expansion of the information already available to the accident flight crew in the AFM.

reduced acceleration during the takeoff ground roll, as well as the reduced braking effectiveness during an aborted takeoff.

The AFM for the accident airplane did not contain, and was not required to contain, FAA-approved operational planning tables with data for operations on a contaminated runway. According to Air Castle personnel, it required its pilots to obtain contaminated runway performance planning data from the “blue charts” and the SimuFlite Canadair Challenger QRH, which were informational supplements that were not FAA-approved.[41] According to the QRH available to the flight crew, the required takeoff runway length for the airplane given the runway conditions and the use of anti-ice systems was greater than 11,000 feet. If the flight crewmembers had consulted the contaminated runway charts, they should have properly determined not to attempt such a takeoff, regardless of whether the aircraft was contaminated, because the required runway length was longer than either runway at MTJ. However, because the airplane achieved liftoff speed within an appropriate amount of time within an appropriate runway distance, the issues related to the effects of bleed air system use on takeoff performance are not directly pertinent to the cause of this accident.

However, the takeoff runway planning issues further illustrate that the flight crew did not act with proper regard for the serious hazards posed by the winter weather conditions and did not adhere to company procedures that would have addressed these hazards. Specifically, neither the captain nor the first officer recognized that specific performance planning tables must be consulted for contaminated runway operations; the captain failed to confirm that a proper preflight inspection was conducted of the skin surfaces of the airplane for ice contamination; the captain failed to have the airplane deiced prior for takeoff; and the captain failed to provide a takeoff briefing as required by Air Castle, thus not maintaining the safety margins built into the briefing procedures that reinforce crew coordination and awareness of operational hazards.

Neither the captain nor the first officer had operational experience in significant winter weather conditions. No record was found that would suggest that the captain had any experience flying in the conditions that existed at MTJ on the day of the accident involving frost, ice, or snow conditions producing adherence of contamination to the skin surfaces of the airplane. Although the first officer’s logbook was not recovered for examination, his training and previous employment experience were in Florida, and there was no documentation to suggest that he had ever operated an airplane in winter weather conditions. In addition, although the captain and the first officer had received company training during initial indoctrination on winter weather operations, their actions suggest that the training was not effective.

The captain and the first officer’s actions also demonstrated poor CRM. For example, during the pretakeoff planning discussions regarding the possibility of takeoff from the 7,500-foot runway, the first officer initially told the captain he believed they would need 8,000 feet of runway for takeoff. The captain then asked the first officer to look up the required takeoff runway length for the airplane in various configurations. Each configuration requested by the captain resulted in a subsequently shorter runway length required, and they decided that, with

[41] The supplements were not approved by the FAA and, according to the AFM, were to have been kept separate from the FAA-approved contents of the AFM. According to the Canadair CL-600-2A12 Airplane Operating Manual, Supplementary Procedures, Section 1, when runway contamination is present, takeoff distance and V1 must be determined with reference to the data shown in the AFM Unapproved Supplement 2, “Operation On Contaminated Runways.”

no engine bleed air anti-ice systems in use (which was not appropriate for the weather conditions), the runway length required was 7,200 feet (which did not consider the runway contamination). When the captain subsequently asked the first officer if he agreed that they could use the 7,500-foot runway, the first officer stated, "these number [sic] are always conservative anyway."

Even after the planning discussions, right before takeoff roll, the CVR suggests the captain sought to change the airplane's configuration to include the use of engine cowl anti-ice, and he did not discuss any performance data regarding this change. The first officer failed to challenge the captain's noncompliance with company procedures and Federal regulations and, therefore, failed to provide a second pilot's critical independent evaluation and monitoring function, as required by his position.

Air Castle did provide some CRM training to all of its pilots, but it did not provide, and was not required to provide, a formal CRM training program. The FAA currently requires formal CRM training programs for Part 121 operators only. The Safety Board notes, that, in the case of the captain, formal CRM training might have assisted him in directing crew attention to the hazards posed by the weather, in complying with company procedures, and in promoting effective crew coordination. In the case of the first officer, who was recently hired, such formal CRM training might have reinforced the company's support of crewmembers' authority to challenge a captain's actions under such circumstances.

Both the captain and the first officer, who were based in the eastern time zone, crossed multiple time zones (ranging from 3 hours behind to 6 hours ahead of eastern standard time) in the 4 days before the accident. In addition, their available rest time occurred at times that varied greatly from their typical rest schedules in the eastern time zone. Studies have shown that such rapid crossings of time zones can produce fatigue through sleep disruption, with pilots experiencing difficulty initiating or maintaining sleep during and after the trip; the resulting circadian disruption can lead to increased fatigue and impaired performance. The actual amount and quality of sleep received by the captain and the first officer could not be determined. Regardless, their improper preflight planning and failure to deice the airplane reflected fundamental operational shortcomings that were independent of fatigue.

PROBABLE CAUSE

The Board concludes that the probable cause of this accident was the flight crew's failure to ensure that the airplane's wings were free of ice or snow contamination that accumulated while the airplane was on the ground, which resulted in an attempted takeoff with upper wing contamination that induced the subsequent stall and collision with the ground. A factor contributing to the accident was the pilots' lack of experience flying during winter weather conditions.

RECOMMENDATIONS

For additional information on these recommendations, please refer to the safety recommendation letters.

New Recommendations

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

> Develop visual and tactile training aids to accurately depict small amounts of upper wing surface contamination. Require all commercial airplane operators to incorporate these training aids into their initial and recurrent training. (A-06-42)

Also, the Safety Board makes the following recommendation to the Department of Transportation:

> Require that, for 14 *Code of Federal Regulations* (CFR) Part 135 on-demand air taxi flights, the following information be provided to customers and passengers at the time the flight is contracted and at any point there is a subsequent change: the name of the company with operational control of the flight, including any "doing business as" names contained in the Operations Specifications; the name of the aircraft owner; and the name(s) of any brokers involved in arranging the flight. (A-06-43)

Previously Issued Recommendation Reiterated and Reclassified

As a result of its investigation of this accident, the National Transportation Safety Board reiterates the following recommendation, which was issued to the Federal Aviation Administration on December 2, 2003:

> Require that 14 *Code of Federal Regulations* (CFR) Part 135 on-demand charter operators that conduct dual-pilot operations establish and implement a Federal Aviation Administration-approved crew resource management training program for their flight crews in accordance with 14 CFR Part 121, subparts N and O. (A-03-52)

On May 2, 2006, the Safety Board classified Safety Recommendation A-03-52 (previously classified "Open—Acceptable Response") "Open—Unacceptable Action."

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

MARK V. ROSENKER
Acting Chairman

ELLEN ENGLEMAN CONNERS
Member

DEBORAH A. P. HERSMAN
Member

KATHRYN O. HIGGINS
Member

Adopted: May 2, 2006

BOARD MEMBER STATEMENT

Member Deborah A. P. Hersman's Concurring Statement:

On November 28, 2004, a chartered jet crashed in Montrose, Colorado due to icing on the wings. The subsequent investigation by the Safety Board determined that the crew did not properly inspect the wings for ice contamination before attempting to take off from the Montrose airport.

We could limit our analysis on that narrow determination, but I believe the Safety Board should not take this approach. This accident investigation is significant for a number of reasons. It represents a whole subset of the aviation industry that is growing and that deserves more attention from us and more oversight by the FAA. While it is true that the crew's failure to inspect the wings for contamination was the immediate cause of the accident, there were factors involved in this accident that are factors in other Part 135 air charter operations that should be addressed before they become causal to future accidents involving air charters.

According to the FAA aircraft registry data reported in the GAATA Survey, the number of turbine-powered aircraft involved in general aviation and on-demand Part 135 operations in 2004 was about 17,700, including about 9,200 jets. The number of jets involved in general aviation and on-demand Part 135 operations increased 29% between 1999 and 2004 (From 7,120 in 1999 to 9,298 in 2004) This growth in popularity is due to the convenience of point-to-point service between thousands of airports versus scheduled commercial service between just 500 airports.

There are three basic types of business jet operations: 1) corporate jets that fly under Part 91 by professional crews; 2) corporate jets that fly under Part 91 by non-professional crews (for example, business professionals with pilot's licenses); and 3) air charters flown professionally and on-demand under Part 135. The focus of the discussion in this Board meeting was on Part 135 air charter operations.

In the mid-1990's, FAA dissolved its Part 135 branch in the flight standards department. FAA reinstated the branch last year, but that segment of the industry went without significant FAA headquarters' oversight for nine years, coincidentally during a time of steady growth in the industry. Many Part 135 charter operators have maintained very safe operations despite a lack of hands-on oversight from the FAA. Their equipment is expertly maintained, and their crews are trained.

NTSB data show that corporate jets flown by professional crews under part 91 (.28 accidents per 100,000 hours in 2004) have accident rates that are comparable to scheduled air carriers (.16 accidents per 100,000 hours in 2004). Some, however, operate jets on a shoestring budget with inadequately experienced or trained crews and/or flimsy maintenance practices. These type of operations, especially when operated as on-demand Part 135 charters or air taxis can produce accident rates as high as .49 accidents per 100,000 hours. Unfortunately, the air charter consumer has few practical options for finding out the differences between safe and unsafe operators, and FAA's oversight and information about these operators provide virtually no help.

The May 5 Board meeting was concerned with one accident by one Part 135 air charter operator. The probable cause of the accident was the crew's failure to adequately inspect the airplane's wings for ice contamination before they took off for the second leg of their flight. The purpose of today's meeting was not to simply condemn this particular air charter operator, Air Castle, or its crew for this tragic error. We also had the opportunity today to shine a light on some of the weaknesses in oversight of the air charter industry, which should be addressed as this industry continues to grow.

FAA Oversight

FAA's oversight beyond certification of Part 135 air charter operators appears to be lacking. In researching this industry to prepare for this Board meeting, I heard again and again from industry experts that the FAA's oversight of Part 135 operators is mostly limited to review of paperwork without actual physical inspections of equipment, maintenance, or operational practices. This void has given rise to a specialized industry of private aviation auditors who, by request and for a fee, conduct thorough reviews of Part 135 air charter operators. They are hired sometimes by air charter consumers (for example, corporations that frequently charter aircraft for their executives), and sometimes by an air charter operator itself. Air Castle was audited by one of these private auditors, Wyvern, who gave it a generally good review in a thorough and detailed report.

General Electric Corporate Air Transport, who arranges travel for executives of a large corporation and who arranged the charter for this particular trip, knew enough about air charter operations to insist that any Part 135 air charter operator it hired would have to have an acceptable rating by Wyvern. GE Corporate Air Transport routinely dealt with an air charter operator called Key Air, also Wyvern-approved, but Key Air had no available aircraft to accept this particular trip. In this situation, Key Air brokered the trip to another Wyvern-approved operator, Air Castle, which leased the accident aircraft from Hop-a-Jet. Although Air Castle was approved by Wyvern, the crew used by Air Castle on the accident aircraft was not. Subsequent to the accident, Wyvern correspondence with GE Corporate Air Transport revealed that in June 2004, Hop-a-Jet was suspended from recommended status following an accident at Ft. Lauderdale Executive Airport.

GE Corporate Air Transport undoubtedly believed it was diligent in insisting on certain standards for the air charter operator, but it did not get what it probably thought it was getting; it did not get a Wyvern-approved crew and it is not clear from the information in the docket whether the aircraft was Wyvern-approved. If an experienced corporate travel organization like GE Corporate Air Transport can be so fooled, how easy is it for others with perhaps far less savvy and market power to hire air charter services that are less safe than they expect?

The use of third party auditors to fill the void created by the lack of information/oversight by the FAA is not a new issue. In 2002, the Safety Board investigated the accident involving a Part 135 air charter operator, Aviation Charter, in which Senator Paul Wellstone of Minnesota was killed. The Safety Board stated in the accident report that, "Although the Federal Aviation Administration's surveillance of Aviation Charter was in accordance with its standard guidelines, it was not sufficient to detect the discrepancies that existed at Aviation Charter." One year prior to the accident, a private safety auditor, ARG/US, had given Aviation Charter a "dnq" ("does not qualify") rating. In addition to private safety auditors, the Department of Defense conducts audits of operators it is considering for contract services.

Transparency in Air Charter Operations

In the wake of the Montrose and Teterboro accidents, the issue of operational control, wet leases, and charter brokers have been addressed by FAA and DOT through various publications and meetings.[42] The Safety Board has also dealt with appeals of FAA enforcement actions resulting from such activities that were deemed to be unsafe by FAA (Administrator v. Darby Aviation dba Alphajet International, Inc.). While FAA and DOT are making an effort to address several areas of concern, much of their guidance is not mandatory.

Under sanctioned FAA practices, certificate-holders are authorized to conduct business under other fictitious business names, or DBAs ("doing business as") as long as they list the alternate names in their Operations Specifications (OpsSpecs). A review of the docket reveals that there are several DBAs associated with Air Castle, including Global Airways, Global Aviation, and California Airways. Air Castle was owned by a Winfair Aviation Group, which also owned several other companies including Hop-a-Jet. Hop-a-Jet leased the accident aircraft to Air Castle dba Global Aviation. An LA Times article on the accident[43] quotes an Air Castle official stating that Air Castle was a "paper company" owned by Jet Alliance, and a Hop-a-Jet official stated that the accident aircraft was leased to Jet Alliance. After the accident, all aircraft were removed from the Air Castle operating certificate and placed on another certificate issued to Worldwide Jet Charter, LLC. Jet Alliance is listed as a dba of Worldwide Jet. This recitation of corporate structure may not be entirely accurate because contained in the docket for this investigation are three organizational charts, all of them different. The only thing that is clear is that it is all very confusing. This confusion does not mean that Air Castle was not safe; investigators, in fact, found that Air Castle was generally a safe operator. But it begs the question whether the FAA has the resources and the ability to oversee these complex business arrangements. And if Federal investigators who spent months looking at this accident cannot clearly decipher the structure and relationships of the various entities associated with the certificate-holder, how could consumers be expected to untangle the threads of ownership and responsibility?

The need for greater transparency in the operations of Part 135 air charter service is crucial. While transparency by itself will not prevent an accident caused by a crew inexperienced in flying in winter conditions, it could go a long way to exposing safety weaknesses of some operators within the industry and prevent them from finding shelter under diverse and undisclosed corporate names.

It has been a long-standing practice in Part 121 operations to reveal to the consumer the name of the carrier with operational control, in accordance with 14 CFR 119.9. DOT requirements in this area have resulted in transparency in the relationships between commuter

[42] The FAA has issued the following: "Wet Lease Policy Guidance," (proposed, 70 *Federal Register* 61684), "Responsibility for Operational Control During Part 135 Operations and the Use of a DBA," (notice issued June 10, 2005) and "The Role of Air Charter Brokers in Arranging Air Transportation." (notice issued October 8, 2004).

[43] "High-Profile Business Plane Crashes Belie Safety", Los Angeles Times, Ralph Vartabedian, December 12, 2004.

airlines and major carriers, as well as code share arrangements. In the interest of transparency and disclosure, I believe it is appropriate to provide similar information to customers of Part 135 charter operations. Therefore, I am very pleased that the Safety Board today voted to issue a recommendation to DOT to require on Part 135 air taxi flights that the following information be provided to customers and passengers at the time the flight is contracted, and at any point there is a subsequent change: the name of the company with operational control of the flight, including any "doing business as" names contained in the OpsSpecs; the aircraft owner; and the name(s) of any brokers involved in arranging the flight.

Contaminated Runways

The draft report states on page 20:

> "The AFM for the accident airplane did not contain, and was not required to contain, FAA-approved operational planning tables with data for operations on a contaminated runway. According to Air Castle personnel, the accident airplane's AFM contained a section labeled 'unapproved supplements' that contained performance planning tables that were not FAA-approved (commonly referred to as blue charts because they are printed on blue paper) that included data for operations on contaminated runways. According to Air Castle personnel, the company required that pilots obtain performance data for operations on contaminated runways from the blue charts or from the SimuFlite Canadair Challenger Quick Reference Handbook (QRH) that was on board the airplane."

Operations on contaminated runways have the potential to be extremely hazardous if accurate distances are not used in pilot decision-making. The FAA does not offer pilots any specific guidance in calculating additional runway length factors when operating on contaminated runways. Such information should not be optional. In fact, it is required by the European Union's Joint Aviation Authorities (JAA). If Boeing, Airbus, Bombardier, or Gulfstream sell aircraft for use in Europe, the performance data for operations on contaminated runways is provided by the manufacturer in order to obtain certification. In the U.S., the same information is considered supplemental.

The transcript of this crew's pre-flight conversation indicates that they were relying on the takeoff lengths corresponding to performance data for dry runways, which was the only runway performance information required to be in the AFM. If they had consulted the appropriate charts for contaminated runway performance, they would have realized that with both the engine inlet cowl and wing bleed anti-ice "on" as required by the weather conditions, they could not have taken off on runway 31 (7,500 ft) or runway 35 (10,000 ft). While use of the information would not have changed the fact that the crew made a decision to take off with contamination on the upper surface of the wings, the charts may have forced them to be more cognizant of the seriousness of the weather conditions that day in Montrose.

A footnote in the Safety Board's draft report notes that "The supplements were not approved by the FAA, and according to the AFM, were to have been kept separate from the FAA-approved contents of the AFM." Regulatory authorities in other countries require this information in AFMs, so should the FAA.

At today's meeting, I asked the Safety Board to consider issuing a recommendation to FAA to require that AFMs include FAA-approved operational planning tables with data for operations on runways that are wet or contaminated. Ideally, this data should be developed by the manufacturer and flight-tested. My preference would have been to add this recommendation to the Montrose accident report. However during the Board Meeting there was a discussion of the upcoming public hearing, tentatively scheduled for June 20, 2006, on the runway accident that occurred last December at Midway Airport in Chicago. Since the subject of operating aircraft on contaminated runways will be more fully discussed in that forum, I concurred with the suggestion from the Chairman to consider the recommendation in the near-term through the Safety Board's notation process.

Member Higgins joined Member Hersman in this concurring statement.

Deborah A. P. Hersman

May 5, 2006