National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 23, 2010

In reply refer to: A-10-10 through -34
A-05-1, A-05-14, and
A-07-13 (Reiteration)

The Honorable J. Randolph Babbitt
Administrator
Federal Aviation Administration
Washington, DC 20591

On February 12, 2009, about 2217 eastern standard time,[1] a Colgan Air, Inc., Bombardier DHC-8-400 (Q400),[2] N200WQ, operating as Continental Connection flight 3407, was on an instrument approach to Buffalo-Niagara International Airport, Buffalo, New York, when it crashed into a residence in Clarence Center, New York, about 5 nautical miles northeast of the airport. The 2 pilots, 2 flight attendants, and 45 passengers aboard the airplane were killed, one person on the ground was killed, and the airplane was destroyed by impact forces and a postcrash fire. The flight, which originated from Liberty International Airport (EWR), Newark, New Jersey, was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121. Night visual meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board (NTSB) determined that the probable cause of this accident was the captain's inappropriate response to the activation of the stick shaker, which led to an aerodynamic stall from which the airplane did not recover. Contributing to the accident were (1) the flight crew's failure to monitor airspeed in relation to the rising position of the low-speed cue,[3] (2) the flight crew's failure to adhere to sterile cockpit procedures, (3) the captain's failure to effectively manage the flight, and (4) Colgan Air's inadequate procedures for airspeed selection and management during approaches in icing conditions.[4]

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

[2] According to Bombardier's website, the DHC-8 has been known as a Q-series airplane since 1996. The Q400 entered service in 2000.

[3] A low-speed cue is shown as a red and black vertical bar that extends from the bottom right of the vertical scale. The low-speed cue warns pilots of an inappropriately low airspeed for the airplane configuration or operating condition. If the airplane's indicated airspeed (IAS) is less than or equal to the IAS at the top of the low-speed cue, the stick shaker activates.

[4] For more information, see *Loss of Control on Approach, Colgan Air, Inc., Operating as Continental Connection Flight 3407, Bombardier DHC-8-400, N200WQ, Clarence Center, New York, February 12, 2009*, Aircraft Accident Report NTSB/AAR-10/01 (Washington, DC: NTSB, 2010), which is available on the NTSB's website at <http://www.ntsb.gov/publictn/2010/AAR1001.pdf>.

Background

While the airplane was climbing to its assigned cruise altitude of 16,000 feet, the captain (the flying pilot) turned the reference speeds switch (commonly referred to as the ref speeds switch) on the ice protection panel above his seat to the increase position. According to the Bombardier Q400 Airplane Flight Manual (AFM), the ref speeds switch was to be set to the increase position before an airplane entered icing conditions (or upon initial detection of icing) and was to be set to the off position when the airplane was aerodynamically clean (that is, all ice was removed from the visible leading edges of the wing and wing tips).

For the accident airplane, turning the ref speeds switch from the off to the increase position lowered the angle-of-attack (AOA) reference for stick shaker activation and raised the position of the low-speed cue on the pilots' indicated airspeed (IAS) displays by about 15 knots. As a result, the airplane would have the same (or greater) performance margins relative to the stall speed during operations in icing conditions as it would have with a clean configuration as long as the landing airspeeds were appropriately increased to remain above the stall warning threshold.[5]

The first officer (the monitoring pilot) had entered planned landing information, including the intended runway and the airplane's landing weight, into the aircraft communications addressing and reporting system (ACARS) for transmittal to AeroData, a vendor under contract with Colgan that supplied real-time landing performance data. However, she did not enter the keywords "icing" or "eice [en route icing accumulation]," despite the icing conditions at the time, the deicing equipment in use, the ref speeds switch in the increase position, and the expected landing conditions. ACARS returned the landing performance data to the airplane, showing a reference landing speed (V_{ref}) of 118 knots and a go-around speed (V_{ga}) of 114 knots, but these speeds were not appropriate for an airplane configured for flight in icing conditions. (If the first officer had entered either "icing" or "eice," then the V_{ref} would have been 138 knots, which would have included a 20-knot icing increment.) The first officer provided the speeds to the captain, and he did not challenge them.

About 2216:09, the low-speed cue began to rise from the bottom of the IAS display as the airspeed slowed. However, the flight crew made no remarks and took no actions that were consistent with the recognition of this cue. Also, because the autopilot altitude hold mode was engaged when the airplane leveled off at 2,300 feet, the autopilot continued to add nose-up pitch trim to maintain altitude as the airspeed slowed.[6] During the time that the low-speed cue was in view, the airplane's pitch trim increased from 1° to 7° nose up, and the pitch attitude of the airplane increased from 3° to 9° nose up. Neither pilot remarked about the increasing pitch attitude, even though it was a cue indicating that airspeed was slowing. In addition, an airspeed

[5] During the May 2009 public hearing for this accident, a Bombardier engineering manager testified that, to remain above the stall warning threshold with the ref speeds switch set to increase, flight crews would need to increase landing airspeeds between 15 and 25 knots depending on the flap setting.

[6] The pitch trim actuators can be either automatically controlled by the autopilot or manually controlled by a pilot. For the accident flight, after the autopilot was selected on (shortly after takeoff), the FDR pitch trim adjustments were applied by the autopilot.

trend vector (an upward- or downward-pointing arrow) on the IAS display predicted the airspeed at which the airplane would be flying in 10 seconds, and the numbers on the airplane's IAS display changed from white to red as the airplane reached the calculated stick shaker activation speed.

The cockpit voice recorder (CVR) recorded the activation of the stick shaker[7] about 2216:27, and flight data recorder (FDR) data showed that the activation occurred at an AOA of about 8°, a load factor of 1 G,[8] and an airspeed of 131 knots,[9] which was consistent with the AOA, airspeed, and low-speed cue during normal operations when the ref speeds switch was selected to the increase position. The airplane was not close to stalling at the time. However, because the ref speeds switch was selected to the increase (icing conditions) position, the stall warning occurred at an airspeed that was 15 knots higher than would be expected for a Q400 in a clean (no ice accretion) configuration. Stick shakers generally provide pilots with a 5- to 7-knot warning of an impending stall; thus, as a result of the 15-knot increase from the ref speeds switch, the accident flight crew had a 20- to 22-knot warning of a potential stall.[10]

CVR and FDR data indicated that, when the stick shaker activated, the autopilot disconnected automatically. The captain responded by applying a 37-pound pull force to the control column, which resulted in an airplane-nose-up elevator deflection, and adding power. In response to the aft control column movement, the AOA increased to 13°, pitch attitude increased to about 18°, load factor increased from 1.0 to about 1.4 Gs, and airspeed slowed to 125 knots. In addition, the speed at which a stall would occur also increased.[11] The airflow over the wing separated as the stall AOA was exceeded, leading to an aerodynamic stall and a left-wing-down roll that eventually reached 45°, despite opposing flight control inputs.

The airplane experienced several roll oscillations during the wing aerodynamic stall. FDR data showed that, after the roll angle had reached 45° left wing down, the airplane rolled back to the right through wings level. After the stick pusher activated,[12] the captain applied a 41-pound pull force to the control column, and the roll angle reached 105° right wing down. After the second stick pusher activation, the captain applied a 90-pound pull force, and the roll angle

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[7] The stick shaker warns a pilot of an impending wing aerodynamic stall through vibrations on the control column, providing tactile and aural cues. Stalls occur when the AOA of the wing—that is, the angle between the direction of airflow and the wing—exceeds a critical angle at which the air can no longer flow smoothly over the wing. Stalls disrupt lift, increase drag, and decrease roll control.

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

[9] The airspeed was 13 knots higher than the V_{ref} that the flight crew had set but 7 knots lower than the V_{ref} icing speed.

[10] The airspeed at which an airplane would stall can be increased if the airplane experiences measurable loads (that is, variation from a 1 G load) because of, for example, maneuvering or external forces. The increased stall speed with loads greater than 1 G would erode the stall warning margin.

[11] Numerous combinations of airspeed and load factor can result in the stall AOA being exceeded. The stall warning margin that existed at the time of stick shaker activation was consumed by the increase in load factor during the pull-up maneuver, leading to the stall AOA being exceeded at an airspeed that was much higher than the 1 G stall speed.

[12] The Q400 stick pusher applies an airplane-nose-down control column input to decrease the wing AOA after an aerodynamic stall.

reached about 35° left wing down and then 100° right wing down. After the third stick pusher activation, the captain applied a 160-pound pull force. The final roll angle position recorded on the FDR was about 25° right wing down. At that time, the airplane was pitched about 25° airplane nose down.

The NTSB's investigation found that variable periods of snow and light-to-moderate icing were present during the accident airplane's approach to the airport and that some ice accumulation was likely present on the airplane. However, the airplane responded to control inputs as expected, given the calculated ice accretion at the time, until the wing stalled, and an aircraft performance study and simulations showed that the airplane experienced minimal performance degradation because of the ice accretion. Thus, the NTSB concluded that the captain's inappropriate aft control column inputs in response to the stick shaker caused the airplane's wing to stall and that the minimal aircraft performance degradation resulting from ice accumulation did not affect the flight crew's ability to fly and control the airplane. The NTSB also concluded that the captain's response to stick shaker activation should have been automatic, but his improper flight control inputs were inconsistent with his training and were instead consistent with startle and confusion.

Strategies to Prevent Monitoring Failures

The flight crewmembers failed to monitor the airplane's pitch attitude, power, and especially its airspeed and failed to notice, as part of their monitoring responsibilities, the rising low-speed cue on the IAS display. Multiple strategies can be used to protect against catastrophic outcomes resulting from these and other monitoring failures, including flight crew training, flight deck procedures, and low-airspeed alert systems.

Flight Crew Monitoring Training

The NTSB has long recognized the importance of flight crew monitoring skills in accident prevention. In its 1994 safety study of 37 flight crew-involved major accidents, the NTSB found that, for 31 of these accidents, inadequate monitoring and/or cross-checking had occurred.[13] The study also found that flight crewmembers frequently failed to recognize and effectively draw attention to critical cues that led to the accident sequence, which was further demonstrated by the circumstances of this accident.

As part of its safety study, the NTSB issued Safety Recommendations A-94-3 and -4 to the Federal Aviation Administration (FAA) concerning the need for enhanced training of pilot monitoring skills. The recommendations stated, in part, that the FAA should require Part 121 air carriers to provide line operational simulation training that "allows flightcrews to practice, under realistic conditions, non-flying pilot functions, including monitoring and challenging errors made by other crewmembers" and that the carriers' initial operating experience (IOE) should include training and experience for check airmen and pilots "in enhancing the monitoring and

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

challenging functions." On January 16, 1996, the NTSB classified these recommendations "Closed—Acceptable Alternate Action" based on the FAA's revised training guidance (Advisory Circular [AC] 120-51B), which emphasized the importance of monitoring.

Another accident involving monitoring failures occurred in February 2005 when a Cessna Citation crashed on approach to Pueblo, Colorado. In its report on the accident,[14] the NTSB cited the flight crew's "failure to effectively monitor and maintain airspeed" as part of the probable cause and issued Safety Recommendation A-07-13, which asked the FAA to do the following:

> Require that all pilot training programs be modified to contain modules that teach and emphasize monitoring skills and workload management and include opportunities to practice and demonstrate proficiency in these areas.

On May 17, 2007, the FAA stated that it would consider identifying, in its work program, a list of required inspections that would reemphasize, to regional office and flight standards district office (FSDO) managers, the need to validate the training that was already required and verify its effectiveness. On September 10, 2008, the NTSB stated that such a list would be responsive to the intent of the recommendation as long as the list provided a strong emphasis on the monitoring and workload management components of a crew resource management (CRM) program. The NTSB classified the recommendation "Open—Acceptable Response."

The importance of monitoring was referenced in some of Colgan's guidance to its pilots[15] and was discussed and evaluated during simulator training and IOE. However, the company did not provide specific pilot training that emphasized the monitoring function. Further, the company's CRM training did not explicitly address monitoring or provide pilots with techniques and training for improving their monitoring skills.[16]

During public hearing testimony, the National Aeronautics and Space Administration (NASA)-Ames Research Center chief scientist for aerospace human factors stated that people have limited attention and must select from among those features in their environment to direct their attention. Also, distractions and interruptions can increase workload and redirect attention, thus complicating the monitoring task. As a result, effective monitoring requires active effort.

To improve monitoring skills, pilots must proactively seek information and ask questions. The NASA chief scientist testified that current pilot training programs do not typically train these skills in a systematic manner. The NTSB concludes that the monitoring errors made by the accident flight crew demonstrate the continuing need for specific pilot training on active

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[14] For more information, see 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).

[15] The company flight manual made only minimal reference to the responsibilities of the monitoring pilot during approach profiles.

[16] The company's current training for CRM/threat and error management presents information on the importance of monitoring as a strategy to detect and prevent errors.

monitoring skills. Almost 3 years have passed since Safety Recommendation A-07-13 was issued, and more than 2.5 years have passed since the FAA described to the NTSB the planned actions to address the recommendation. Since that time, the FAA has reported no further action on this recommendation, even after receiving the NTSB's September 2008 response letter. Therefore, the NTSB reiterates Safety Recommendation A-07-13 and reclassifies it "Open—Unacceptable Response."

Flight Deck Procedures

The FAA has developed guidance on the design of procedures to facilitate pilot monitoring and cross-checking. These procedures are contained in an appendix to AC 120-71A, "Standard Operating Procedures for Flight Deck Crewmembers." The guidance provides examples of and supporting rationale for standard operating procedures that promote monitoring. The guidance also recommends establishing standard operating procedures to support improved monitoring during climb, descent, and approach.

Colgan's standard operating procedures did not include speed targets during approaches; these targets would have facilitated the detection of speed deviations by the monitoring pilot. Colgan also lacked standardized procedures for setting airspeeds and using the ref speeds switch, which did not promote effective cross-checking between airspeeds and the switch's status. If such procedures had been in place, then the flight crew might have detected the inconsistency between the 118-knot V_{ref} (a non-icing speed) and the position of the ref speeds switch (icing conditions assumed) and ensured that a V_{ref} of 138 knots (an icing speed) was selected. Further, although company procedures required the flying pilot to make a 1,000-foot callout when changing altitudes, the director of flight standards stated that the callout was not required before the altitude alerter sounded. Such a practice can impede monitoring because flight crews may become passive and wait for an automated backup system to prompt their required callout.[17] After the accident, the company introduced the "VVM" (verbalize, verify, and monitor) program to improve flight crew monitoring.[18]

The NTSB concludes that Colgan Air's standard operating procedures at the time of the accident did not promote effective monitoring behavior. The NTSB is concerned that other air carriers' standard operating procedures may also be deficient in this area. Therefore, the NTSB recommends that the FAA require Part 121, 135, and 91K[19] operators to review their standard operating procedures to verify that they are consistent with the flight crew monitoring techniques described in AC 120-71A; if the procedures are found not to be consistent, revise the procedures according to the AC guidance to promote effective monitoring.

[17] This practice, known as primary backup reversion, is characterized by a human operator using an automated backup system as the primary signal to be monitored.

[18] Colgan also discussed the importance of monitoring in its revised CRM/threat and error management course. Also, the company's revised Flight Operations Policies and Procedures Manual reinforced this training by stating that all pilots were expected to "actively demonstrate monitoring and challenging" as a CRM skill during line operations.

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

Low-Airspeed Alert Systems

The low-speed cue and the stick shaker on the Q400 were intended to warn the pilots of an impending stall. In this case, even though both systems functioned as designed, neither pilot responded appropriately to prevent the stall. Features on the airspeed display, including the indicated airspeed, trend vector, and low-speed cue, should have provided the pilots with adequate time to detect the rising low-speed cue and respond appropriately. However, distraction and workload considerations may have made it difficult for the pilots to visually detect features on the airspeed display depicting the development of this condition (including the trend vector and the low-speed cue), so a redundant aural alert might have provided them with an effective warning about the decreasing airspeed in relation to the rising position of the low-speed cue.

In its report on the October 2002 King Air A100 accident in Eveleth, Minnesota,[20] the NTSB found that the pilots had allowed the airspeed to decrease to dangerously low levels while attempting to execute a nonprecision instrument approach during instrument meteorological conditions. As a result, the airplane entered an aerodynamic stall from which the flight crew did not recover. Because the flight crew failed to recognize that the stall was imminent, the NTSB concluded that the development of and requirement for the installation of a low-airspeed alert system could substantially reduce the number of accidents and incidents involving a flight crew's failure to maintain airspeed.

On December 2, 2003 the NTSB issued Safety Recommendations A-03-53 and -54, which asked the FAA to do the following:

> Convene a panel of aircraft design, aviation operations, and aviation human factors specialists, including representatives from the National Aeronautics and Space Administration, to determine whether a requirement for the installation of low-airspeed alert systems in airplanes engaged in commercial operations under 14 *Code of Federal Regulations* Parts 121 and 135 would be feasible, and submit a report of the panel's findings. (A-03-53)
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> If the panel requested in Safety Recommendation A-03-53 determines that a requirement for the installation of low-airspeed alert systems in airplanes engaged in commercial operations under 14 *Code of Federal Regulations* Parts 121 and 135 is feasible, establish requirements for low-airspeed alert systems, based on the findings of this panel. (A-03-54)

On October 3, 2006, the FAA stated that it had formed a team to assess the feasibility of low-airspeed alert systems. On April 3, 2007, the NTSB stated it was encouraged that the FAA had formed the team and would begin addressing the recommendation. As a result, the recommendation was classified "Open—Acceptable Response."

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[20] For more information, see National Transportation Safety Board, *Loss of Control and Impact With Terrain, Aviation Charter, Inc., Raytheon (Beechcraft) King Air A100, N41BE, Eveleth, Minnesota, October 25, 2002*, Aircraft Accident Report NTSB/AAR-03/03 (Washington, DC: NTSB, 2003).

During the almost 6 years since the NTSB issued Safety Recommendations A-03-53 and -54, (which were reiterated in July 2006 after another event involving decreasing airspeed and loss of control),[21] accidents and incidents involving a lack of flight crew awareness of decreasing airspeed have continued, indicating that existing stall warnings are not a reliable method for preventing inadvertent hazardous low-speed conditions. The NTSB notes that human factors concerns associated with a low-airspeed alert do not require more than 6 years of study for a solution to be implemented.[22]

The NTSB notes that several other airplanes certificated under 14 CFR Part 25, including the Boeing 747-400 and 777, provide pilots with an amber band on the airspeed display above the low-speed cue. This amber band typically represents the airspeed between the stall warning speed and the minimum maneuvering speed. Operations are not normally conducted with airspeeds in the amber band, which, in effect, provides pilots with a visual indication of a developing low-speed condition before the onset of the stall warning.

AC 25-11A, “Electronic Flight Displays,” discusses the visual design of low-speed awareness cues and states, “the preferred colors to be used are amber or yellow to indicate that the airspeed has decreased below a reference speed that provides adequate maneuver margin, changing to red at the stall warning speed. The speeds at which the low speed awareness bands should start should be chosen as appropriate to the airplane configuration and operational flight regime. For example, low speed awareness cues for approach and landing should be shown starting at Vref with a tolerance of +0 and -5 knots.”

The NTSB concludes that the Q400 airspeed indicator lacked low-speed awareness features, such as an amber band above the low-speed cue or airspeed indications that changed to amber as speed decrease toward the low-speed cue, which would have facilitated the flight crew’s detection of the developing low-speed situation. Therefore, the NTSB recommends that the FAA require that airspeed indicator display systems on all aircraft certified under 14 CFR Part 25 and equipped with electronic flight instrument systems depict a yellow/amber cautionary band above the low-speed cue or airspeed indicator digits that change from white to yellow/amber as the airspeed approaches the low-speed cue, consistent with AC 25-11A, “Electronic Flight Displays.”

At the public hearing for this accident, an FAA certification specialist testified that current certification rules under 14 CFR 25.1329 indicate that there should be speed protection and/or alerting within the normal speed range while under flight guidance system (autopilot) control. The certification specialist stated, “there should be low speed alerting occurring prior to

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[21] The recommendations were reiterated in a safety recommendation letter addressing an incident involving American Eagle flight 3008, a Saab 340 airplane that experienced a loss of control during icing conditions. The letter also addressed three similar Saab 340 incidents investigated by the Australian Transport Safety Bureau and stated, “if the flight crews had been alerted to the rapid airspeed decrease in a timely fashion, they may have been able to take corrective action and perhaps avoid the stall.”

[22] After the March 19, 2001, incident involving Comair flight 5054, a low-airspeed alert system was developed for Embraer EMB-120 airplanes. The system was designed to provide pilots with an aural and a visual alert of low airspeed while operating in icing conditions. FAA Airworthiness Directive 2001-20-17, effective October 22, 2001, mandated installation of the system on the EMB-120.

stall warning, if you're under flight guidance system or autopilot control. And that low speed alerting can take many forms, but it needs to be aural and visual."[23]

On July 9, 2009, the FAA issued a notice of proposed rulemaking (NPRM) for flight crew alerting, which included a requirement that alerts necessitating immediate crew awareness be presented using two sensory modalities. For example, a visual alert accompanied by an aural alert can help to capture and focus a pilot's attention in the event that the pilot is not looking at the alerting cue. In this accident, the pilots did not likely see the rising low-speed cue on the IAS display, the downward-pointing trend vector, or the airspeed indications change to red. As a result, the NTSB concludes that an aural warning in advance of the stick shaker would have provided a redundant cue of the visual indication of the rising low-speed cue and might have elicited a timely response from the pilots before the onset of the stick shaker. Therefore, the NTSB recommends that, for all airplanes engaged in commercial operations under 14 CFR Parts 121, 135, and 91K, the FAA require the installation of low-airspeed alert systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-speed condition. Because of the FAA's inactivity with regard to Safety Recommendations A-03-53 and -54, the NTSB classifies the recommendations "Closed—Unacceptable Action/Superseded" and classifies Safety Recommendation A-10-12 "Open—Unacceptable Response."

Pilot Professionalism

Leadership Training

The captain was responsible for setting the appropriate tone in the cockpit and managing communications and workload in a manner that promoted professionalism and adherence to standard operating procedures. On the basis of his actions during the flight, including the late performance of checklists and callouts because of an ongoing conversation,[24] the captain showed inadequate leadership. His failure to establish the appropriate cockpit tone during the initial stages of the operation[25] and show strong command authority during the flight is disconcerting, especially because he had been a captain for more than 2 years.

In March 1998, the FAA mandated CRM training for all Part 121 operators. CRM training helps facilitate effective crew communication and coordination and the use of available resources to protect against error. The concepts associated with CRM training have been

[23] The Q400 was certificated before the amendment to Section 25.1329. AC 25.1329-1B, "Approval of Flight Guidance Systems," states, "standard stall warning and high-speed alerts are not always timely enough for the flight crew to intervene to prevent unacceptable speed excursions during FGS [flight guidance system] operation." The AC also states, "a low speed alert and a transition to the speed protection mode at approximately 1.13 Vsr [reference stall speed] for the landing flap configuration has been found to be acceptable." In addition, the AC states, "low speed protection alerts should include both an aural and visual component."

[24] The captain and the first officer engaged in conversations for much of the flight. Once the airplane had descended through 10,000 feet (about 2206:37), sterile cockpit procedures, prohibiting nonpertinent conversations within the cockpit, were required. However, the flight crewmembers engaged in a nonpertinent conversation after that time.

[25] Between the time that the airplane left the gate at EWR and the time that it was cleared for takeoff, 1 hour 33 minutes had elapsed. During the ground time at EWR that was captured by the CVR, the flight crew engaged in lengthy conversations that were not directly related to the operation, which set the tone for the flight.

expanded to include techniques for threat and error detection, management, and mitigation. Many operators integrate CRM concepts in their training programs and evaluate CRM skills during simulator training and line observations. Colgan's CRM training included 5 slides (of 45 slides total) that addressed command, leadership, and leadership styles.

In contrast, Part 121 operators are not required to provide upgrading captains with specific training on the leadership skills necessary to make the transition from second-in-command to pilot-in-command (PIC). For many new captains, including the accident captain, the initial upgrade represents the first time in which they are held responsible for leading and managing multiple crewmembers during air carrier operations. Because of the PIC's critical role in establishing and maintaining safe operating conditions, upgrading captains would greatly benefit from specific training on command and leadership skills.

The captain upgraded in October 2007; at that time, Colgan provided to its upgrading captains a 1-day training course on duties and responsibilities. Although the director of crewmember and dispatcher training stated that the course was designed to help a new captain make the transition to the new role, the NTSB's review of the course content showed that it focused on the administrative duties associated with becoming a captain. The upgrade training course did not contain significant content applicable to developing leadership skills, management oversight, and command authority.

Some air carriers provide leadership training to their upgrading captains. For example, one regional air carrier expanded its leadership training, from 2 to 8 hours, so that additional information on leadership skills could be presented. This change was made in response to an unacceptable level of training failures (primarily because of leadership and judgment factors) for upgrading captains.[26] The expanded course contained modules on leadership, authority, and responsibility; briefing and debriefing scenarios; decision-making processes, including those during an emergency; dry-run line-oriented flight scenarios; and risk management and resource utilization.

Industry changes (including two-pilot cockpits and the advent of regional carriers) have resulted in opportunities for pilots to upgrade to captain without having accumulated significant experience as a first officer in a Part 121 operation. Without these important opportunities for mentoring and observational learning, which characterize time spent in journeyman pilot positions, it may be difficult for a pilot to acquire effective leadership skills to manage a multicrew airplane. In addition, airlines must instill their leadership values and safety culture in their captains because they are the ones who are ultimately responsible for the safety of each flight.

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[26] The company's captain upgrade first-time failure rate had reached 22 percent when the target was 10 percent. The company's principal operations inspector stated that the failures had involved "captain thinking skills" and not "stick and rudder skills." For more information, see National Transportation Safety Board, *Crash of Pinnacle Airlines Flight 3701, Bombardier CL-600-2B19, N8396A, Jefferson City, Missouri, October 14, 2004*, Aircraft Accident Report NTSB/AAR-07/01 (Washington, DC: NTSB, 2007).

At the public hearing for this accident, the Air Line Pilots Association's (ALPA) safety committee chairman discussed the need for companies to provide leadership skills to upgrading captains and for captains to set the proper tone in the cockpit. The principal operations inspector (POI) for Colgan stated, during a postaccident interview, that training in this area was important and should be required.

The NTSB concludes that specific leadership training for upgrading captains would help standardize and reinforce the critical command authority skills needed by a PIC during air carrier operations. Some operators are already providing this training, but others are not. Therefore, the NTSB recommends that the FAA issue an AC with guidance on leadership training for upgrading captains at Part 121, 135, and 91K operators, including methods and techniques for effective leadership; professional standards of conduct; strategies for briefing and debriefing; reinforcement and correction skills; and other knowledge, skills, and abilities that are critical for air carrier operations. The NTSB further recommends that the FAA require all Part 121, 135, and 91K operators to provide a specific course on leadership training to their upgrading captains that is consistent with the AC requested in Safety Recommendation A-10-13.

Sterile Cockpit and Standard Operating Procedures

The pilots were involved in nonpertinent conversation during all phases of flight, including those that are defined as critical by the sterile cockpit rule. For example, the pilots' nonpertinent conversation during the final minutes of the descent (which included a discussion of their previous experiences flying in icing conditions) distracted them from their operational tasks. In addition, the pilots deviated from standard operating procedures with the timing of checklists during the descent.[27]

Colgan expected sterile cockpit procedures to be included in a captain's briefing and adhered to during training, checkrides, and line operations. Most company pilots interviewed after the accident stated that sterile cockpit adherence was good and that pilots deviated rarely from sterile cockpit procedures. Company and FAA oversight before the accident did not identify any problems with sterile cockpit adherence, but some deviations were identified after the accident.

Colgan stated that it had provided pilots with information on sterile cockpit procedures during ground school indoctrination training, but a review of all slides presented during the training at the time of the accident found none that specifically addressed sterile cockpit procedures. After the accident, the company revised its training program, and recurrent training

[27] For example, Colgan's Q400 company flight manual indicated that the cruise checklist should be performed after the airplane attained its assigned cruising altitude, as the flying pilot leveled the airplane and allowed it to accelerate to the maximum operating limit speed minus 10 knots. However, the captain called for the cruise checklist about 2138:47, which was about 2.5 minutes after the airplane had accelerated to cruise speed. Also, Colgan's Flight Operations Policies and Procedures Manual stated that approach briefings should generally be accomplished before the top of the descent (when the crew's workload was expected to be minimal), but the captain did not start this briefing until 2204:16, as the airplane descended below 12,000 feet. In addition, the manual also required a callout by the flying pilot when the airplane was descending through 10,000 feet, but the captain was conducting the approach briefing at that time and omitted the callout.

now addresses the importance of sterile cockpit procedures. Also, the company's chief pilot issued guidance on sterile cockpit adherence, including a reminder that no extraneous conversation of any kind could take place when sterile cockpit procedures were in effect.[28]

The NTSB is concerned that, during the accident flight, neither pilot seemed hesitant to engage in nonpertinent conversation or demonstrated correcting behavior when the other pilot deviated from sterile cockpit procedures. These facts suggest that nonpertinent conversation among company pilots during critical phases of flight was not unusual.

The primary reason for 14 CFR 121.542, otherwise known as the sterile cockpit rule, is to ensure that a pilot's attention is directed to operational concerns during critical phases of flight and is not redirected or degraded because of nonessential activities or conversation. The NTSB has investigated accidents demonstrating the catastrophic effects of pilot deviations from Section 121.542 and standard operating procedures. For example, in August 2006, the flight crew of Comair flight 5191 attempted to depart from the wrong runway, which resulted in an accident that killed 49 of the 50 people on board. The NTSB determined that the flight crew's nonpertinent conversation during taxi, which resulted in a loss of positional awareness, was a contributing factor to the accident. The NTSB also found that the flight crew's noncompliance with standard operating procedures had most likely created an atmosphere in the cockpit that enabled the crew's errors.[29] Nonpertinent conversation during a critical phase of flight and noncompliance with standard operating procedures were also issues found during the investigation of the Colgan accident.

Other recent accidents have identified similar issues involving a breakdown in cockpit discipline and noncompliance with the sterile cockpit rule.[30] Although it is difficult to identify a specific reason for this behavior, industry data have shown that pilots who had intentionally deviated from standard operating procedures were three times more likely to make other types of errors, mismanage more errors, and find themselves in more undesirable situations compared with those flight crewmembers who had not intentionally deviated from procedures.[31]

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[28] In addition to these changes, Colgan incorporated a discussion of accidents and incidents involving sterile cockpit breakdowns to its CRM/threat and error management training. Also, Colgan procedures contained an expanded definition of sterile cockpit periods, including ± 1,000 feet of level-off altitude when making altitude changes and when approaching the top of descent on crossing restrictions and pilot-discretion descents.

[29] For more information, see *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: NTSB, 2007).

[30] These accidents include the Corporate Airlines flight 5966 accident and the Pinnacle Airlines flight 3701 accident. For information about the Corporate Airlines accident, see National Transportation Safety Board, *Collision with Trees and Crash Short of Runway, Corporate Airlines Flight 5966, British Aerospace BAE-J3201, N875JX, Kirksville, Missouri, October 19, 2004*, Aircraft Accident Report NTSB/AAR-06/01 (Washington, DC: NTSB, 2006).

[31] These data are from the Line Operations Safety Audit (LOSA) Collaborative, which is a network of researchers, safety professionals, pilots, and airline representatives who collaborate to provide, among other things, oversight and implementation of LOSA and a forum for information exchange regarding LOSA. Deviations from sterile cockpit procedures are among the types of intentional noncompliance that can be detected through LOSA observations. In January 2007, the NTSB issued Safety Recommendation A-07-9 to require Part 121 operators to incorporate LOSA observations into their oversight programs. This recommendation is currently classified "Open—Acceptable Response." Colgan has begun to implement a LOSA program.

Nevertheless, most airline and FAA personnel have stated, after accidents, that no precursors to such deviations were identified during their previous oversight activities. The Q400 APM for Colgan acknowledged that an inspector's observations of flight crew performance might not be representative of the crew's usual performance.

On February 7, 2006, the NTSB issued Safety Recommendation A-06-7, which asked the FAA to direct the POIs of all Part 121 and 135 operators to reemphasize the importance of strict compliance with the sterile cockpit rule. In response to this recommendation, the FAA issued Safety Alert for Operators (SAFO)[32] 06004 on April 28, 2006, to emphasize the importance of sterile cockpit discipline. As a result of the FAA's action, the NTSB classified Safety Recommendation A-06-7 "Closed—Acceptable Action" on November 9, 2006. However, the lasting effect of this SAFO is questionable given that the Comair flight 5191 accident occurred only 4 months after the SAFO was issued and the Colgan accident happened less than 3 years after the SAFO's issuance.

At the public hearing for this accident, an FAA manager stated that the agency has been addressing sterile cockpit issues through, among other actions, published guidance and oversight activities by inspection personnel.[33] The NTSB identified only one FAA AC or handbook—the Instrument Procedures Handbook (FAA-H-8261-1A)—that references an accident involving the lack of sterile cockpit discipline.[34] In addition, this publication does not include information that outlines the origin of the sterile cockpit rule, its rationale, and an explicit discussion of the safety consequences associated with the failure to adhere to sterile cockpit procedures during critical phases of flight.

Also at the public hearing, the Colgan director of flight standards testified that postaccident observations of company pilots revealed only "minor" sterile cockpit deviations, such as an individual pilot remark about something either heard on the radio or seen. The flight standards director stated that, in such instances, the other pilot would not respond to the comment. However, the NTSB recognizes that any nonpertinent remark during critical phases of flight has the potential to be distracting. Multiple opportunities exist during noncritical phases of flight to allow flight crewmembers to communicate, establish trust, and build rapport, but, during critical phases of flight, all conversations need to relate solely to the operation of the flight. These conversations should follow standard operating procedures and include the use of standard phraseology, which are proven tools for safely operating aircraft.

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[32] FAA Order 8000.87A, dated October 24, 2006, stated that a SAFO contained important, often critical, safety information and recommended (nonregulatory) action to be taken voluntarily by the operators identified in the SAFO. (This order replaced FAA Order 8000.87, dated August 29, 2005, which introduced SAFOs.)

[33] These publications include AC 120-71A, "Standard Operating Procedures for Flight Deck Crewmembers"; AC 120-74A, "Parts 91, 121, 125, and 135 Flightcrew Procedures During Taxi Operations"; AC 120-51E, "Crew Resource Management Training"; and AC 91-73A, "Part 91 and Part 135 Single-Pilot Procedures During Taxi Operations."

[34] The handbook references the September 1974 Eastern Air Lines flight 212 accident, which was caused by the flight crew's lack of altitude awareness at critical points during the approach as a result of poor cockpit discipline. For more information, see National Transportation Safety Board, *Eastern Air Lines, Inc., Douglas DC-9-31, N8984E, Charlotte, North Carolina, September 11, 1974*, Aircraft Accident Report NTSB/AAR-75/09 (Washington, DC: NTSB, 1975).

Even though the responsibility for sterile cockpit adherence is ultimately a matter of a pilot's own professional integrity, the NTSB notes that pilots work within a context of professionalism created through the mutual efforts of the FAA, operators, and pilot groups. These stakeholders need to work together to provide clear and unwavering guidance that helps to instill sound principles of professionalism and adherence to standard operating and sterile cockpit procedures. The stakeholders also need to provide detailed guidance on these topics to new commercial pilots as well as instruction and reinforcement on the topics to pilots throughout their career.

On January 23, 2007, the NTSB issued Safety Recommendation A-07-8, which asked the FAA to do the following:

> Work with pilot associations to develop a specific program of education for air carrier pilots that addresses professional standards and their role in ensuring safety of flight. The program should include associated guidance information and references to recent accidents involving pilots acting unprofessionally or not following standard operating procedures.

On April 13, 2007, the FAA stated that it would meet with ALPA, the Air Transport Association, the Regional Airline Association, and other groups to determine an effective approach for addressing these issues. On January 22, 2008, the NTSB stated that the FAA's planned action would be appropriate after the development of an educational program that conveyed the necessary safety information and classified the recommendation "Open—Acceptable Response." However, in the 3 years since the issuance of Safety Recommendation A-07-8, the FAA has not produced guidance material or developed a program that meets the intent of the recommendation.[35]

The NTSB recognizes that most pilots strive to fly professionally and adhere to standard operating and sterile cockpit procedures. However, the continuing failure of some pilots to refrain from nonpertinent conversation during critical phases of flight erodes proven margins of safety provided by the strict adherence to standard operating procedures, as demonstrated by the circumstances of this accident.

More than 28 years have elapsed since sterile cockpit rulemaking was enacted based on the NTSB's investigation of the Eastern Air Lines accident and the professional conduct recommendations that resulted from the investigation.[36] However, industry action is still needed

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[35] In contrast, the FAA has created instructional materials on other aviation safety-related issues. For example, to address the increasing problem of runway incursions, the FAA distributed to all pilots a multimedia presentation and printed guidance on the issue. The presentation addressed runway safety, discussed accidents and operating rules, and offered best practices and techniques. Such an approach could be effective in addressing breakdowns in pilot professionalism and sterile cockpit discipline, especially if examples of accidents are included with standard operating procedures and best practices to help focus attention on the reasons for the standards and the potential results of not following them.

[36] Safety Recommendation A-74-85 asked the FAA to "initiate a movement among the pilots associations to form new professional standards committees and to regenerate old ones. These committees should: a) monitor their

to provide all pilots with guidance discussing (1) the importance of following standard operating procedures, adhering to sterile cockpit procedures, and maintaining professionalism during aircraft operations and (2) the costs to safety when pilots do not operate according to these standards.

The NTSB concludes that, because of the continuing number of accidents involving a breakdown in sterile cockpit discipline, collaborative action by the FAA and the aviation industry to promptly address this issue is warranted. Therefore, the NTSB recommends that the FAA (1) develop, and distribute to all pilots, multimedia guidance materials on professionalism in aircraft operations that contain standards of performance for professionalism; best practices for sterile cockpit adherence; techniques for assessing and correcting pilot deviations; examples and scenarios; and a detailed review of accidents involving breakdowns in sterile cockpit and other procedures, including this accident and (2) obtain the input of operators and air carrier and general aviation pilot groups in the development and distribution of these guidance materials. As a result of this new recommendation, and because the FAA has not taken any action in 3 years to address Safety Recommendation A-07-8, the recommendation is reclassified "Closed—Unacceptable Action/Superseded."

Fatigue Mitigation

Although both pilots had flown during the week before the accident, their schedules were within flight and duty time requirements and were not excessive in terms of accumulated flight time or duty periods worked. However, each pilot made an inappropriate decision to use the crew room[37] to obtain rest before the accident flight. The NTSB found that the captain had experienced chronic sleep loss[38] and that both he[39] and the first officer[40] had experienced

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ranks for any unprofessional performance, b) alert those pilots who exhibit unprofessionalism to its dangers and try, by example and constructive criticism of performance required, to instill in them the high standards of the pilot group, c) strengthen the copilot's sense of responsibility in adhering to prescribed procedures and safe practices, and d) circulate the pertinent information contained in accident reports to pilots through professional publications so that members can learn from the experience of others." Safety Recommendation A-74-86 asked the FAA to "develop an air carrier pilot program, similar to the general aviation accident prevention program (FAA Order 8000.8A), that will emphasize the dangers of unprofessional performance in all phases of flight. The program could be presented in seminar form, using audio/visual teaching aids, to call to the pilots' attention all facets of the problem." Both recommendations were classified "Closed—Acceptable Action" on March 10, 1977.

[37] The EWR regional chief pilot stated, during a postaccident interview, that the company's crew room at the airport has couches, recliners, and a television. The chief pilot described the room as a place for pilots to relax but indicated that the room was not adequate for rest before a trip.

[38] On February 9, 2009, the captain commuted from his home in the Tampa, Florida, area to EWR, arriving about 2005 for a 2-day trip to begin the next day. His last known activity on February 9 ended about 2247. The captain was reported to have stayed overnight in the crew room at EWR. On February 10 and 11, 2009, the captain had a report time of 0530, and his last known activities those days ended between 2130 and 2200. The captain's earlier awakening time required for the report times, and his rest away from home, would have produced some chronic sleep loss.

[39] On the day of the accident, the captain was scheduled to report to EWR at 1330. Because his duty period on February 11, 2009, had ended about 1544, he had a 21-hour, 16-minute scheduled rest period before his report time. However, at 0310 on February 12, the captain logged into the company's CrewTrac computer system, which Colgan pilots use to access company-related information, including crew schedules and company messages. This activity would have meant that he had, at a minimum, a 5-hour opportunity for sleep followed by another sleep opportunity of about 4 hours. (The captain had logged into the CrewTrac system again at 0726.) The captain's actual

interrupted and poor-quality sleep during the 24 hours before the accident. Because the effects of fatigue can exacerbate performance failures, its role in the pilots' performance during the flight could not be ruled out. The NTSB concludes that the pilots' performance was likely impaired because of fatigue, but the extent of their impairment and the degree to which it contributed to the performance deficiencies that occurred during the flight cannot be conclusively determined.

The NTSB has had a long-standing concern about the need to mitigate the effects of fatigue in aviation. Reducing accidents and incidents caused by human fatigue has been on the NTSB's Most Wanted List of Transportation Safety Improvements since 1990. Also, the NTSB has issued numerous safety recommendations addressing fatigue, including Safety Recommendation A-06-10, which was issued on February 7, 2006, as part of the investigation of the Corporate Airlines flight 5966 accident. Safety Recommendation A-06-10 asked the FAA to do the following:

> Modify and simplify the flight crew hours-of-service regulations to take into consideration factors such as length of duty day, starting time, workload, and other factors shown by recent research, scientific evidence, and current industry experience to affect crew alertness.

On September 9, 2009, the FAA stated that an aviation rulemaking committee had developed recommendations on flight and duty time limitations and rest requirements for Part 121 and 135 operators. The FAA indicated that it was reviewing the recommendations (which have not been publicly released) and that it had planned to publish a science-based fatigue NPRM in December 2009.[41]

On December 10, 2009, in testimony before the Subcommittee on Aviation, U.S. Senate Committee on Commerce, Science, and Transportation, the FAA Administrator stated that the FAA was reviewing the aviation rulemaking committee's recommendations on flight and duty time limitations and rest requirements but that additional analysis needed to be completed,

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sleep during this period is unknown. However, his sleep would have been further interrupted and would likely have been of poor quality because he was again staying in the crew room. As a result, the captain would not have had an opportunity to restore his sleep loss from the previous 2 days. Also, it would have been difficult for the captain to nap in the crew room during the day based on observations of his activities before the flight (which included office work, watching television, and talking on the telephone or with other company pilots).

[40] On February 11, 2009, from about 1951 to about 2330 Pacific standard time (0230 eastern standard time), the first officer traveled as a jumpseat passenger on a cargo airplane from Seattle-Tacoma International Airport, Seattle, Washington, to Memphis International Airport (MEM), Memphis, Tennessee, and was reported to have slept 90 minutes during the flight. On February 12, from about 0418 to about 0623, the first officer traveled as a jumpseat passenger on a cargo airplane from MEM to EWR and was reported to have slept the entire flight. She was observed awake, and electronic records (telephone, text, and computer) showed activity from the time of her arrival at EWR to about 0732. Afterward, no activities on the part of the first officer were recorded until a text message she sent at 1305.

[41] The FAA's last fatigue-based NPRM was 95-18, "Flight Crewmember Duty Period Limitations, Flight Time Limitations, and Rest Requirements," which was issued on December 20, 1995. The NTSB provided comments on the NPRM, indicating that the proposed rule did not (1) include effective mechanisms to address flight operations during the circadian night and circadian trough and (2) recognize the fatigue associated with multiple takeoffs and landings. No changes in the rules regarding flight time and rest requirements were made after the issuance of the NPRM. On November 23, 2009, the FAA officially withdrew the NPRM.

precluding the NPRM from being issued by the end of December 2009. The administrator also stated that the NRPM would be published as soon as possible.

On December 29, 2009, the NTSB stated that the FAA, after years of inaction, appeared to be on the verge of taking the recommended actions with regard to flight time limitations, duty period limits, and rest requirements for Part 121 and 135 pilots.[42] The NTSB noted that the FAA had proposed publishing the NPRM in early 2010 but stated that the FAA had not informed the NTSB of the specific revisions that the NPRM would include. Because the NTSB was not able to determine at that time whether the revisions would fully satisfy the intent of Safety Recommendation A-06-10, the recommendation remained classified "Open—Unacceptable Response."

One of the stated purposes of SAFO 06004 (as discussed previously) was to "call attention to fatigue as one of the most important elements to be addressed in CRM training." Even though the SAFO recommended that Part 121 directors of safety become familiar with the document's contents, a review of Colgan's CRM course material at the time of the accident showed only a minimal mention of fatigue. The company's director of crewmember and dispatcher training stated that fatigue was discussed as part of a review of situational awareness. Also, Colgan personnel were not able to describe how the company had incorporated the fatigue-related information in the SAFO.

Colgan had a nonpunitive fatigue policy in effect at the time of the accident[43] but did not have a formal fatigue management program in place at the time. (Such a program was still not in place as of January 2010.) After the accident, the company revised its CRM course material to include a specific discussion of fatigue management and the hazards associated with fatigue. Also, in April 2009, Colgan issued an operations bulletin to its pilots addressing the company's fatigue policy, causes of fatigue, recognition of fatigue and its effects on performance, and prevention of fatigue by effectively using rest.[44]

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[42] The NTSB's response to Safety Recommendation A-06-10 also addressed Safety Recommendations A-94-194 and A-95-113. Safety Recommendation A-94-194 asked the FAA to "revise the Federal Aviation Regulations contained in 14 CFR Part 135 to require that pilot flight time accumulated in all company flying conducted after revenue operations—such as training and check flights, ferry flights and repositioning flights—be included in the crewmember's total flight time accrued during revenue operations." Safety Recommendation A-95-113 asked the FAA to "finalize the review of current flight and duty time regulations and revise the regulations, as necessary, within 1 year to ensure that flight and duty time limitations take into consideration research findings in fatigue and sleep issues. The new regulations should prohibit air carriers from assigning flight crews to flights conducted under 14 CFR Part 91 unless the flight crews meet the flight and duty time limitations of 14 CFR Part 121 or other appropriate regulations." Both of these recommendations, which were also on the NTSB's Most Wanted List, had been classified "Open—Unacceptable Response."

[43] The policy allowed pilots to remove themselves from flight status without reprisals if they were too tired to fly. Pilots calling in fatigued would not be paid for that flight segment if it were over their 75-hour monthly guarantee. The company's chief pilot indicated that the company tracked fatigue calls to identify trends but that no consistent factors had been identified. Also, the Colgan POI had not received any complaints about the company's administration of the fatigue policy.

[44] This information has also been incorporated into the Flight Operations Policies and Procedures Manual revision, dated September 20, 2009. In addition, the NTSB notes that ALPA has developed resources for pilots on preventing fatigue, recognizing fatigue symptoms, and mitigating the effects of fatigue.

In December 2009, Colgan issued a read-and-sign memo to its pilots and flight attendants, which stated that the company's nonpunitive fatigue policy was being increasingly abused. (The company indicated that crewmembers had been calling in fatigued without a valid reason.) The memo also detailed interim changes to Colgan's fatigue policy. The memo stated that, effective December 31, 2009, fatigue calls would not be accepted if a crewmember was returning from rest periods or personal time off duty (and did not properly use the time off). The memo indicated that the safety department would consider mitigating circumstances preventing a rest period from being fully utilized when evaluating a fatigue call. In addition, the memo stated that the company was working with its pilot and flight attendant unions to establish a comprehensive fatigue program, including a review board process, by February 15, 2010.

At the public hearing for this accident, the FAA manager of air carrier operations stated that fatigue mitigation in aviation was a joint responsibility between the operator and the pilot. He also stated that company fatigue information can help pilots better manage their time off from work. The accident pilots did not wisely manage their time off from work, which contributed to the development of fatigue. In particular, the pilots chose to use the crew room during their rest period, and their quality of sleep was affected by this decision.[45] Although the crew room was supposed to be a quiet area with couches and recliners, it was not isolated and was subject to interruptions, sporadic noise and activity, lights, and other factors that prevent quality rest. As a result, neither pilot made use of the opportunity to obtain quality sleep and be as rested as possible before the flight.

Company personnel stated that sleeping overnight in the crew room was against policy because the room was not an adequate rest facility.[46] However, the captain used the crew room for overnight sleeping on February 9 and 11, which indicates that the company was not effectively enforcing its policy.

In addition, the first officer's decision to begin a transcontinental commute about 15 hours before her scheduled report time without having an adequate rest facility affected her ability to begin the trip as rested as possible. The commute from Seattle International Airport, Seattle Washington, to Memphis International Airport (MEM), Memphis, Tennessee, and then from MEM to EWR did not afford her an opportunity for an uninterrupted sleep period. Even though the first officer arrived at EWR about 7 hours before her scheduled report time, this time period was less than her normal sleep period, and evidence indicates that she could not have used all of that time for sleep. Company guidance at the time of the accident, however, did not discourage pilots from commuting on the same day that a trip was scheduled to begin.[47]

[45] The NTSB notes that strategic napping in crew rooms during breaks is an effective countermeasure for pilot fatigue and that this type of rest would be appropriate use of a crew room. However, the accident captain used the EWR crew room for all of his sleep opportunity before the flight, and the first officer used the crew room for most of her sleep opportunity.

[46] The EWR regional chief pilot issued policy guidance in May 2008 stating that crewmembers were responsible for their own overnight accommodations and that sleeping in the crew room was prohibited and would have disciplinary consequences.

[47] The previous edition of the Colgan Flight Crewmember Policy Handbook (dated February 2006) stated that pilots should not commute to their base on the same day that they are scheduled to work. The handbook version current at the time of the accident was dated March 2008 and did not include this guidance.

The company's commuting policy addressed ways to ensure that pilots were able to arrive at their base and report for duty on time, but the policy did not reference ways to mitigate fatigue resulting from commuting. Testimony at the public hearing by ALPA's air safety chairman indicated that Colgan's commuting policy was consistent with industry practices.

Commuting is considered a privilege for air carrier pilots because they are not required to live within a certain distance of their assigned base. Commuting may also be considered a necessity for air carrier pilots because of possible changes in the industry, including base closures, and the cost of living at some bases.[48] To accommodate the need for rest areas when commuting, pilots often have "crash pads" (shared rooms or apartments) at their base if their operator does not provide crew rest facilities for uninterrupted sleep. However, Colgan did not have such a facility at EWR (or its other bases), and neither the captain nor the first officer had a crash pad.[49]

Pilots who commute have a significant responsibility to make sure that they arrive fit for duty and are able to maintain this fitness throughout the duration of their assigned duty period.[50] However, pilots who do not commute also have a responsibility to be fit for duty, and certain circumstances can affect a noncommuting pilot's ability to obtain adequate rest. For example, in its investigation of the Federal Express flight 1478 accident in Tallahassee, Florida, the NTSB found that the captain (who lived close to MEM, the departure airport) had received interrupted sleep[51] during the two nights that preceded the accident because he had been taking care of the family dog, whose health was deteriorating. The captain described his sleep during that time as "marginal" and "not really good." The captain reported that he had received 3.5 hours of "pretty good" sleep before reporting about 0200 for the accident flight. The NTSB concluded that the captain was likely impaired by fatigue and that the impairment contributed to his degraded performance, especially in the areas of crew coordination and monitoring, during the approach to the airport.[52]

The NTSB notes that most pilots are cognizant of their personal responsibility to report to work fit for duty, including having received the proper amount of rest. However, the performance failures that occurred in the Tallahassee accident and this accident demonstrate the negative outcomes that can occur when a pilot fails to obtain adequate rest before a flight. The NTSB concludes that all pilots, including those who commute to their home base of operations, have a personal responsibility to wisely manage their off-duty time and effectively use available rest

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[48] Colgan did not have locality pay for its pilots, but its management personnel received locality pay. In 2008, the average salary of a company Q400 captain and first officer was $67,000 and $24,000, respectively.

[49] Colgan does not require such an arrangement for its commuting pilots.

[50] Air transportation is one mode of transportation that pilots use to commute to their home base. Commuting pilots can also use surface transportation to arrive at their base.

[51] That captain had been released from duty on July 23, 2002, at 2353 and learned of the flight 1478 assignment on July 25 between 1800 and 1830.

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

periods so that they can arrive for work fit for duty; the accident pilots did not do so by using an inappropriate facility during their last rest period before the accident flight.

Companies can take actions to help mitigate fatigue in commuting pilots. Such actions include providing rest facilities, providing assistance to pilots in identifying affordable accommodations, planning flight schedules that support commuting without extended times of wakefulness, and considering ways to evaluate and account for the effect of commuting on subsequent duty periods. With regard to providing rest facilities, the FAA's SAFO 09014, "Concepts for Fatigue Countermeasures in Part 121 and 135 Short-Haul Operations," issued on September 11, 2009, stated that operators "should consider providing crew rest facilities that have rooms away from the general traffic for quiet, comfortable and uninterrupted sleep."[53]

Most of Colgan's EWR-based pilots (93 of 137 pilots) identified themselves as commuters. However, the EWR regional chief pilot stated that he did not know the number of commuting pilots at EWR. This lack of awareness is inconsistent with available information stressing the importance of mitigating hazards associated with crewmember fatigue, including SAFOs 06004 and 09014. The NTSB notes that, although many of the major accidents it has investigated during the last decade involved pilots who commuted, this accident is the first one in which the pilots' rest location has been an issue. Operators have a fundamental responsibility to support their pilots' efforts to mitigate fatigue. However, Colgan did not (1) enforce the policy prohibiting sleeping overnight in the crew room, which was an inappropriate rest facility for uninterrupted sleep, and (2) have in place a formal fatigue management program. The NTSB concludes that Colgan Air did not proactively address the pilot fatigue hazards associated with operations at a predominantly commuter base.

On June 12, 2008, the NTSB issued Safety Recommendations A-08-44 and -45, which asked the FAA to do the following:

> Develop guidance, based on empirical and scientific evidence, for operators to establish fatigue management systems, including information about the content and implementation of these systems. (A-08-44)
>
> Develop and use a methodology that will continually assess the effectiveness of fatigue management systems implemented by operators, including their ability to improve sleep and alertness, mitigate performance errors, and prevent incidents and accidents. (A-08-45)

On August 11, 2008, the FAA noted that, in June 2008, it had hosted an international symposium on fatigue in aviation operations to gather and make public the best available knowledge on fatigue and fatigue mitigations. The FAA also stated that it was developing operations specification guidance for fatigue management for ultra-long-range flights and that lessons learned could likely benefit other flight profiles. On February 3, 2009, the NTSB

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[53] SAFO 09014 also stated that pilots "should understand their responsibility with regard to ensuring that they achieve the required rest so they are properly rested and fit for each assigned or scheduled flight."

encouraged the FAA to ensure that guidance on fatigue management systems be developed for all components of the aviation industry and not only for ultra-long-range operations. Safety Recommendations A-08-44 and -45 were classified "Open—Acceptable Response" pending such guidance.

A fatigue management system, also known as a fatigue risk management system (FRMS), incorporates various components and strategies to mitigate the hazards of fatigue in aviation operations. Components of an FRMS include scheduling policies and practices, attendance policies, education, medical screening and treatment, personal responsibility during nonwork periods, task and workload issues, rest environments, commuting policies, and napping policies. An organizational plan for implementing an FRMS and measuring its ability to mitigate fatigue is important to the success of the system.

Many operators are beginning to implement components of an FRMS, and countermeasures to address issues associated with commuting are expected to be part of an FRMS. However, some operators have not adopted an FRMS, and neither FAA guidance nor rulemaking currently exists in this area. As a result, the NTSB concludes that operators have a responsibility to identify risks associated with commuting, implement strategies to mitigate these risks, and ensure that their commuting pilots are fit for duty. Therefore, the NTSB recommends that the FAA require all Part 121, 135, and 91K operators to address fatigue risks associated with commuting, including identifying pilots who commute, establishing policy and guidance to mitigate fatigue risks for commuting pilots, using scheduling practices to minimize opportunities for fatigue in commuting pilots, and developing or identifying rest facilities for commuting pilots.

Captain's Disapprovals and Training Problems

The captain had received several disapprovals and had experienced training problems throughout his flying career. In October 1991, the captain was disapproved for his initial instrument airplane rating. In May 2002, the captain was disapproved for his initial commercial single-engine land certificate. In March 2004, the captain was disapproved for his initial commercial multiengine land airplane certificate. His established pattern of first-attempt failures might have indicated that he was slow to absorb information, develop skills, and gain mastery or that the training he received was not adequate. This pattern might also have indicated that the captain had difficulty performing required skills while under the stress conditions associated with a checkride.

The captain's initial proficiency check at Colgan, as a first officer on the Saab 340, occurred in October 2005. The captain was graded "train to proficiency" for normal and abnormal procedures. This grade indicated that the captain had completed the checkride but needed additional training on normal and abnormal procedures before he would be considered fully successful. In October 2006, the captain received an unsatisfactory grade on his next flight check, which was his first recurrent proficiency check as a first officer in the Saab 340. In October 2007, the captain attempted a checkride for an FAA airline transport pilot certificate and type rating, but he was initially disapproved.

Even though the captain had demonstrated problems with the three checkrides he had performed, Colgan was not proactively addressing his training and proficiency issues. For example, the company's director of flight standards stated that he had not tracked the captain in terms of his performance. Also, the company's chief pilot stated that he could not recall talking to anyone at the company about the captain's training record. The chief pilot further stated that he was aware of the captain's initial upgrade failure in the Saab 340 and that he told the captain that his next proficiency check needed to be "right on."

The basic concept of attitude instrument flying involves making the proper adjustments to flight and power controls to control aircraft attitude. The NTSB concludes that the captain had not established a good foundation of attitude instrument flying skills early in his career and that his continued weaknesses in basic aircraft control and instrument flying were not identified and adequately addressed.

Remedial Training and Additional Oversight

Because of his continued weaknesses in basic aircraft control and attitude instrument flying, the captain would have been a candidate for remedial training. However, at the time of the accident, the company did not have a formal program for pilots who demonstrated ongoing weaknesses. The company's director of flight standards stated that pilots who were found to be unsatisfactory because of a failed checkride could retrain on the specific failure item and that no further followup would occur if the pilot were found to be satisfactory on the subsequent checkride. This director also stated that, for pilots with multiple unsatisfactory checkrides, he or the flight standards manager would coordinate with the director of crewmember and dispatcher training to assign additional training. (Colgan began a formal pilot monitoring program in August 2009.)

Even though the captain had failed two checkrides since beginning work for Colgan (and was graded "train to proficiency" on another checkride), he had received retraining on the specific failure items and then subsequently passed the checkrides. As a result, no additional training or overall review of his skills as a pilot occurred.

During its investigation of the Federal Express flight 647 accident, the NTSB found that the company had an oversight program that identified flight crewmembers with demonstrated performance deficiencies or training failures and provided them with additional oversight and training. The NTSB's report on the accident concluded that such a proactive program would benefit flight safety at other Part 121 carriers.[54] As a result, on May 31, 2005, the NTSB issued Safety Recommendation A-05-14, which asked the FAA to do the following:

> Require all 14 *Code of Federal Regulations* Part 121 air carrier operators to establish programs for flight crewmembers who have demonstrated performance deficiencies or experienced failures in the training environment that would require

[54] For more information, see National Transportation Safety Board, *Hard Landing, Gear Collapse, Federal Express Flight 647, Boeing MD-10-10F, N364FE, Memphis, Tennessee, December 18, 2003*, Aircraft Accident Report NTSB/AAR-05/01 (Washington, DC: NTSB, 2005).

> a review of their whole performance history at the company and administer additional oversight and training to ensure that performance deficiencies are addressed and corrected.

On April 13, 2007, the FAA stated that it had issued SAFO 06015, “Remedial Training for Part 121 Pilots,” on October 27, 2006. The purpose of the SAFO was to promote voluntary implementation of remedial training for pilots with persistent performance deficiencies. The SAFO recognized that many air carriers had voluntarily incorporated remedial training to supplement their approved training programs and that these remedial training programs were effective in addressing and correcting below-standard pilot performance. For air carriers without a voluntary remedial training program, the SAFO recommended implementing a process to identify pilots with persistent performance deficiencies and/or multiple failures during training and checking. The SAFO advised that this process should (1) review the entire performance history of any pilot in question, (2) provide additional remedial training as necessary, and (3) provide additional oversight by the air carrier to ensure that performance deficiencies were effectively addressed and corrected.

On December 12, 2007, the NTSB stated that the FAA needed to survey all Part 121 operators to determine whether they had taken the action recommended in SAFO 06015. Safety Recommendation A-05-14 was classified “Open—Acceptable Alternate Response” pending completion of this survey and demonstration that all Part 121 carriers had programs to address pilot performance deficiencies or failures during training.

On April 23, 2009, the FAA issued Notice 8900.71, which discussed verification of remedial training for Part 121 carriers. The purpose of the notice was to provide guidance to POIs about a required inspection to determine whether their Part 121 carriers were voluntarily complying with SAFO 06015. The notice also instructed the POIs to complete the inspection within 90 days of the date of the notice. During the public hearing for this accident, the POI for Colgan stated that he was not aware of SAFO 06015.

By definition, SAFOs are advisory only, and the decision to implement a SAFO rests with an operator. The NTSB notes that SAFO guidance may be an acceptable alternate response to a safety recommendation if an FAA survey finds that all of the operators have implemented the recommended actions. However, during public hearing testimony, the FAA’s manager of air carrier training indicated that he did not know which carriers had complied with SAFO 06015.

On October 30, 2009, the FAA indicated that 29 of the 82 Part 121 carriers and 2 of the 24 Part 121/135 carriers had implemented the actions recommended in SAFO 06015. The total number of Part 121 carriers included 27 regional carriers, 6 of which had implemented the SAFO’s recommended actions. On December 10, 2009, the FAA Administrator stated, during his testimony before the U.S. Senate, that two-thirds of the air carriers without advanced qualification programs[55] had systems in place to identify and manage low-time pilots and pilots

[55] An advanced qualification program is a voluntary alternative to the traditional regulatory requirements under Parts 121 and 135 for pilot training and checking.

with persistent performance problems. The administrator also stated that, for those carriers without such systems, additional FAA oversight of their training and qualification programs would be conducted. The FAA's January 27, 2010, fact sheet regarding its report, *Answering the Call to Action on Airline Safety and Pilot Training*,[56] stated that all air carriers (including the 14 carriers that had advanced qualification programs) had developed remedial training programs for pilots that were consistent with the guidance in SAFO 06015.[57]

The NTSB concludes that remedial training and additional oversight for pilots with training deficiencies and failures would help ensure that the pilots have mastered the necessary skills for safe flight. Because the NTSB has not determined the extent that air carrier remedial training programs address pilot performance deficiencies and failures during training, the NTSB reiterates Safety Recommendation A-05-14.

Pilot Training Records

During the investigation of this accident, the NTSB found discrepancies between the dates entered into Colgan's electronic training record system and those in the FAA's certificate records. Specifically, the company's records showed that the captain had failed his initial upgrade proficiency check on the Saab 340 on October 3, 2007, received upgrade line-oriented flight training and upgrade simulator training on October 14, received additional simulator training on October 15, and passed his upgrade proficiency check on that same day. However, FAA certificate records showed that the captain failed his initial Saab 340 upgrade proficiency check on October 15 and passed the check on October 18.

Because Colgan used an electronic record-keeping system to maintain training records for pilots, detailed paper training records were destroyed once the information was entered into the system. As a result, the NTSB was not able to reconstruct the actual sequence of events concerning the captain's Saab 340 upgrade proficiency check. Colgan's director of crewmember and dispatcher training stated that the discrepancy between the company's and the FAA's dates was the result of a clerical error. However, a discrepancy also existed within the company. Specifically, the check airman who conducted the captain's two upgrade proficiency checks stated that the second check was conducted the day after he failed the first check, but the company's electronic records indicated that the second check was conducted 12 days after the failure. These discrepancies in the captain's training records were notable because he had

[56] The FAA's report stated that, as a result of the information that was learned at the Colgan public hearing and subsequent congressional hearings, the Secretary of Transportation and the FAA Administrator initiated, in June 2009, "a Call to Action on Airline Safety and Pilot Training for FAA, air carriers, and labor organizations to jointly identify and implement safety improvements." For more information, see <http://www.faa.gov/library/reports/media/call_to_action_Jan2010.pdf>.

[57] The fact sheet stated that, between June and September 2009, 85 air carriers without advanced qualification programs were inspected to determine if they had remedial training programs that were consistent with the guidance in SAFO 06015. The review determined that 62 air carriers had programs fully in place to meet the guidance for remedial training programs. The fact sheet also stated that, at the time of the review, 15 carriers had some part of a remedial training program in place and that 9 carriers had not implemented any component of a remedial training program. The fact sheet added that, since the time of the review, these 24 air carriers had developed remedial training programs for pilots. The NTSB notes that, although the FAA stated that 85 carriers were reviewed, the results presented were for 86 carriers.

demonstrated previous training difficulties at the company and the events surrounding his upgrade proficiency check warranted further scrutiny.

The company's electronic training record system contained only a basic description of each training event, along with codes for specific items, including the type of airplane, crew position, and instructor name, and a brief statement of any maneuver that was performed unsatisfactorily. If a company manager wanted to reconstruct events from a pilot's training, the manager would need to contact the instructor or check airman who conducted that training. However, interviews with instructors and check airmen who had trained the accident flight crew revealed that some of them could not remember specific details about training events, including the check airman who graded the captain as train to proficiency on his 2005 initial Saab 340 proficiency check and as unsatisfactory on his 2006 recurrent Saab 340 proficiency training. Thus, an air carrier cannot depend solely on the memory of instructors and check airman to identify trends in a pilot's performance.

Colgan's Crewmember and Dispatcher Training Program Manual specified a grading legend to indicate a pilot's performance on each training maneuver.[58] The electronic training record system did not include these grades, even though this information could help company managers determine a pilot's progress during training or events that needed repetitive training. Instructor comments at the time of the training are another source of valuable information regarding a pilot's performance, but such comments were also not included in the company's electronic training record system.

During its investigation of the American Eagle flight 3379 accident,[59] the NTSB was unable to locate instructor comments about the quality of the captain's performance during activities that trained or assessed pilot skills and found that the air carrier's management was unaware of critical aspects of the captain's performance. As a result, on November 15, 1995, the NTSB issued Safety Recommendation A-95-116, which asked the FAA to require all air carriers and their training facilities to maintain pertinent information on the quality of pilot performance. On April 17, 1998, the FAA stated that the inclusion of subjective evaluations by individual instructors, check airmen, or FAA inspectors in a pilot's permanent record might make a training event a punitive experience rather than one in which a pilot could learn from mistakes. On January 3, 2000, the NTSB stated that the FAA had provided a convincing argument about the inappropriateness of subjective information in pilot records and the possibility that pilot training could be negatively affected and classified the recommendation "Closed—Reconsidered."

Detailed paper records of the captain's performance at his previous airline, Gulfstream International Airlines (GIA), were obtained during the investigation. These records provided

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[58] Grading was done on a scale of one through four. The grades ranged from one, which indicated that the pilot understood the maneuver and completed it successfully and that no further training was necessary, to four, which indicated that the pilot did not understand the maneuver or complete it satisfactorily and that further instruction and explanation was needed before further flight or simulator training.

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

greater insight into the captain's performance than the records maintained by Colgan. For example, remarks in the captain's training record at GIA included "airspeed 10 knots below Vref," "repeated deviation from altitude 200-300 feet," and "constant deviations up to full scale on glide slope." It is important to note that these remarks were not subjective evaluations (about which the FAA expressed concern in its response to Safety Recommendation A-95-116); rather, these remarks were criteria-based observations that provided an explanation for the captain's unsatisfactory performance and his need for further training in attitude instrument flying.

At the public hearing for this accident, the POI for Colgan stated that, although the company's training records met regulatory requirements, he was concerned about the lack of detailed information in the system. The FAA's manager of air carrier training stated that electronic record-keeping systems, such as the one used by Colgan, were approved individually for each air carrier by its POI and that his branch, which sets FAA policy on training, does not approve "software of that nature as a standalone item." The FAA manager also indicated that the agency did not require training records to be verified or validated but stated that there should be a way to audit and amend records before they appeared in their final format.

The NTSB notes that the use of electronic pilot training records is acceptable as long as the records contain detailed information from which a pilot's performance during training and checking events can be fully determined. However, the NTSB concludes that Colgan Air's electronic pilot training records did not contain sufficient detail for the company or its POI to properly analyze the captain's trend of unsatisfactory performance. Therefore, the NTSB recommends that the FAA require Part 121, 135, and 91K operators to document and retain electronic and/or paper records of pilot training and checking events in sufficient detail so that the carrier and its POI can fully assess a pilot's entire training performance. The NTSB also recommends that the FAA require Part 121, 135, and 91K operators to include the training records requested in Safety Recommendation A-10-17 as part of the remedial training program requested in Safety Recommendation A-05-14. The NTSB further recommends that the FAA require Part 121, 135, and 91K operators to provide the training records requested in Safety Recommendation A-10-17 to hiring employers to fulfill their requirement under the Pilot Records Improvement Act (PRIA).[60] In addition, the NTSB recommends that the FAA develop a process for verifying, validating, auditing, and amending pilot training records at Part 121, 135, and 91K operators to guarantee the accuracy and completeness of the records.

Pilot Records Improvement Act

Colgan's vice president of administration stated that, as part of a pilot applicant's background check, the company checked the paperwork required by PRIA but that many of the pilots hired by the company did not have previous experience with other airlines, so the information required under PRIA would not be available for them. However, as noted previously, the captain had failed, on three separate occasions, to pass an FAA checkride on his initial

[60] PRIA (49 *United States Code* 44703) was enacted to ensure that air carriers adequately investigated a pilot's background before allowing that pilot to conduct commercial air carrier flights.

attempt.[61] On his application for employment with Colgan, the captain acknowledged only one of the failures.[62] PRIA requirements and FAA guidance (AC 120-68C, "Pilot Records Improvement Act of 1996," dated January 28, 2004) in place at the time that the captain was hired did not require operators to obtain notices of disapproval for flight checks for certificates and ratings.

On January 27, 2005, the NTSB issued Safety Recommendation A-05-1 as a result of the accident involving Air Sunshine flight 527 in Treasure Cay, Great Abaco Island, Bahamas.[63] Safety Recommendation A-05-1 asked the FAA to "require all Part 121 and 135 air carriers to obtain any notices of disapproval for flight checks for certificates and ratings for all pilot applicants and evaluate this information before making a hiring decision."

On September 9, 2005, the FAA stated that requiring all Part 121 and 135 air carriers to obtain these notices would necessitate FAA rulemaking or a change to the PRIA statute. Instead, the FAA stated it would amend AC 120-68C to indicate that a letter of consent signed by a pilot applicant could be used to authorize the FAA to release records of notices of disapproval for flight checks for certificates and ratings to an air carrier making such a request. On November 3, 2006, the NTSB stated that, because the AC information was not mandatory, the FAA needed to survey operators to determine how many were obtaining airman certification records for their pilot applicants from the FAA so that the effectiveness of the FAA's planned action could be assessed. The NTSB classified this recommendation "Open—Acceptable Alternate Response" pending results from the survey and the revision of AC 120-68C.

On November 7, 2007, the FAA issued AC 120-68D, which contained the following information in bold print:

> A request with a signed consent by the pilot/applicant may be used to authorize the FAA to release records of Notices of Disapproval for flight checks for certificates and ratings to an air carrier making such a request. Air carrier representatives involved in the pre-employment screening process may find this additional information helpful in evaluating the pilot/applicant. These requests, however, are not an integral part of the standard PRIA request process.

At the public hearing for this accident, the FAA's program manager for PRIA stated that air carriers have always had the ability to request records from the FAA beyond those required by PRIA as long as the carriers obtained a signed consent statement from the pilot applicant (as

[61] The company stated that its current employment policy does not consider pilots with more than one failed checkride.

[62] The Colgan employment application asked the question, "have you ever failed any proficiency check, FAA check ride, IOE or line check?" The captain responded, "yes, FAA check ride for instrument rating. I missed the NDB [nondirectional beacon] approach, received additional instruction, then repeated the approach and passed."

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

highlighted by the revised AC on PRIA).[64] The program manager stated that he did not know how many air carriers had obtained additional FAA airman certification information for their pilot applicants, but he stated that only one or two air carriers had contacted him for such information. The FAA's manager for air carrier certification also stated that he did not know how many operators were obtaining these data because the survey that the NTSB requested in its November 2006 letter has not been conducted.

The NTSB continues to believe that airman certification information concerning previous notices of disapproval should be included in an air carrier's assessment of the suitability of a pilot applicant. The NTSB also considers notices of disapproval to be safety-related records that must be included in an air carrier's evaluation of a pilot's career progression, along with the detailed training records requested in Safety Recommendations A-10-17 through -20. The revision to AC 120-68 is an interim solution for this safety issue; however, a more permanent action through rulemaking would ensure that air carriers would be required to obtain and evaluate notices of disapprovals for pilot applicants. The NTSB concludes that notices of disapproval need to be considered along with other available information about pilot applicants so that air carriers can fully identify those pilots who have a history of unsatisfactory performance. Because of the FAA's failure to demonstrate voluntary compliance with the advisory information in AC 120-68D, the NTSB reiterates Safety Recommendation A-05-1 and reclassifies it "Open—Unacceptable Response."

Airspeed Selection Procedures

Bombardier specified procedures for the use of the ref speeds switch in the Q400 AFM, which is an FAA-required document. The AFM's procedures for use of the ref speeds switch were included in a section about ice protection features. As previously stated, the procedures indicated that the ref speeds switch was to be turned to the increase position before entering icing conditions or upon initial detection of icing and was to be turned to the off position when the airplane was aerodynamically clean (that is, all ice was removed from the visible leading edges of the wing and wing tips). For a flaps 15 landing with the ref speeds switch in the increase position, pilots needed to increase airspeeds by 20 knots.

Q400 operators were responsible for developing their own procedures for the use of the ref speeds switch that were consistent with the AFM and approved by the FAA. Colgan's procedures for the Q400 were summarized in its company flight manual (CFM), which provided the normal procedures and checklists for flight crews. However, the only direct or indirect references in the Q400 CFM regarding how and when to use the ref speeds switch were the following:

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[64] Although AC 120-68D had not been issued when the captain was a pilot applicant, Colgan could have still obtained a signed consent statement from him that would have allowed the company to obtain and review his three notices of disapproval. Colgan's vice president of administration indicated that, if the company had known about the captain's complete history of FAA checkride failures, then he would have been dismissed from the company. Also, Colgan did not obtain a signed consent statement from the first officer when she was a pilot applicant, even though she was hired after AC 120-68D had been issued.

- In the expanded portion of the after start checklist, which is accomplished before takeoff, a caution note stated, “Ensure the REF SPEEDS switch is set to OFF. If REF SPEEDS switch is set to INCR [increase], the stick shaker may activate on takeoff.”

- An item on the expanded portion of the climb checklist was “ice protection – as req’d,” with the remark, “make sure de-icing and anti-icing switches are set as required for the ambient conditions.”

- An item on the cruise checklist was “24-hr ice protection test – as req’d.” (The ref speeds switch was one of the items to be checked.)

During postaccident interviews, Colgan pilots indicated that they were familiar with the function and operation of the ref speeds switch. However, some company pilots expected to be able to turn off the switch before the approach and landing flight phases, as the airplane descended out of icing conditions. For example, one pilot stated that he had turned the ref speeds switch to the off position after descending out of icing conditions but had planned to “mentally” add 20 knots to the airspeed if ice had resumed on final approach. The captain of a March 2009 flight from EWR to Burlington International Airport (BTV), South Burlington, Vermont, during which the stick shaker activated,[65] stated that she had briefed the landing speeds based on the expectation that the ref speeds switch would be turned from the increase to the off position before the beginning of the approach, but she had forgotten to turn the switch to off, and the first officer had not noticed the position of the switch.

Even though the ref speeds switch is relatively uncommon among air carrier airplanes,[66] it is still important for the switch to be properly matched to the airspeed bugs on those airplanes with the switch installed. In the Q400, airspeed bugs are set by pilots using a rotary knob on their outboard forward panel. Two bugs (represented on the airspeed indicator by a solid blue triangle and an open blue triangle) are available for landing, but the AFM does not require their use or specify how they should be set.

The NTSB found that Q400 operators used different bug speeds for landing. One operator, which had operated the airplane for 10 years, instructed its pilots to set the two available bugs to V_{ref} and $V_{ref\ (ice)}$ for every approach to prevent confusion or the need to reset bugs during an approach if conditions were to change. Another operator, whose director of flight operations was previously a Q400 certification test pilot, had its pilots set the landing bugs to V_{ref} and V_{ga} partly because landings accomplished with the higher (icing) reference speed were rare.

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[65] On March 10, 2009, a Colgan Q400 airplane, N188WQ, was en route from EWR to BTV during night VMC. While descending into BTV, the stick shaker activated, a recovery followed, and the airplane landed at BTV without further incident. During the event, the captain’s response to the stick shaker was consistent with the company’s stall recovery procedures. The captain applied forward pressure on the control column and full power. The airspeed immediately increased, and the stick shaker discontinued.

[66] The NTSB is not aware of any air carrier airplanes that have a ref speeds switch besides the Q400, which is operated by two other U.S air carriers in addition to Colgan.

This operator found that, even when operating during wintertime in a northern climate, most conditions at 1,000 feet above ground level (agl) were such that the landing could be conducted at normal reference speeds.

Colgan chose to have its pilots set either V_{ref} or $V_{ref\ (ice)}$ and V_{ga} as the landing bugs. If V_{ref} had been set and icing conditions were encountered, or if $V_{ref\ (ice)}$ had been set and the airplane was no longer in icing conditions, each pilot was expected to manually reset the airspeeds.

Colgan's guidance on setting landing bugs was contained in the CFM expanded approach checklist. The guidance indicated that pilots were to determine the landing weight and airspeeds and then set the solid blue bug to V_{ref} or $V_{ref\ (ice)}$ and the open blue bug to V_{ga}. Both flight crewmembers were to verify this action by responding "set." This procedure did not mention cross-referencing the airspeed bug settings with the ref speeds switch position (which are independent of each other) and did not include information about the early stall warning that could result from setting normal V_{ref} speeds with the ref speeds switch in the increase position.

After the accident, Colgan issued two operations bulletins pertaining to the ref speeds switch and airspeed settings.[67] The first bulletin, CFM Operations Bulletin 09-001, Speed Bugs for Landing, Icing Definitions, and Ice Equipment Operations, included two warnings and two cautions under the heading, "ref speeds switch." The warnings prohibited (1) moving the ref speeds switch to the increase position below 1,000 feet agl during takeoff and (2) changing the position of the ref speeds switch below 1,000 feet agl during landing. The cautions indicated that (1) if airspeed is within 20 knots of the low-speed cue, then the airspeed must be increased before the ref speeds switch is selected to the increase position, or a stall warning might occur, and (2) if V_{ref} is used for landing, then the ref speeds switch must be selected to the off position, or a stall warning might occur at an airspeed higher than V_{ref}. The bulletin also added a specific response to any ice protection system checklist item and required both flight crewmembers to respond, and it reiterated the proper icing terminology to use with the ACARS system ("icing" or "eice")[68] to ensure that the proper ice speeds were received (from AeroData) for V_{ref} and V_{ga}.

The second bulletin, CFM Operations Bulletin 09-003, REF SPEEDS Switch and Speed Guidance, added a specific line item to the approach checklist, "ref speeds switch – as req'd," with both crewmembers responding. It also provided guidance to flight crews, including a requirement to decide on the position of the switch before the initial approach phase, a prohibition against changing the switch position below 1,000 feet agl, a requirement to use only $V_{ref\ (ice)}$ and $V_{ga\ (ice)}$ with the ref speeds switch set to the increase position, and a statement that the speed bugs could be reset to V_{ref} and V_{ga} if the ref speeds switch was turned to the off position above 1,000 feet agl. A reference to the switch was added to the takeoff profile, and the

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[67] The first bulletin was issued before the BTV event, and the second one was issued after the event.

[68] Before the accident, the CFM showed these terms, which could be used in the optional remarks field of the landing condition screen, but the manual did not elaborate on the effect that the entries would have on the airspeed and landing distances received. Also, the CFM did not mention the need to cross-reference the position of the ref speeds switch when requesting landing performance data using either of the terms.

approach profiles were changed to require a minimum airspeed of 180 knots before lowering the landing gear.

Colgan's flight crew training on the use of the ref speeds switch was incorporated into its ground school curriculum. An examination of the company's slides used during Q400 initial training showed that the function of the ref speeds switch was described in the module on the ice and rain protection system. However, the actual use of the ref speeds switch was not included in the modules on AeroData, ACARS, line-oriented flight training, situational awareness and safety, or winter operations.[69]

Colgan's training manual, which contained the syllabus for Q400 upgrade and transition training, did not specifically mention the ref speeds switch in ground school subject matter sections, including the one on ice and rain protection. Also, the simulator training modules described in the manual made no direct reference to the use of the ref speeds switch. Thus, it is unlikely that crews were appropriately trained on the use the ref speeds switch, especially during simulator training, when it is important for pilots to demonstrate an understanding of the need to match the approach speed bug settings to the position of the ref speed switch.

The NTSB acknowledges Colgan's efforts after the accident to educate its flight crews, through CFM operations bulletins, about the relationship between the ref speeds switch and airspeed bug settings. However, training in this area would further emphasize this relationship. The NTSB concludes that Colgan Air's procedures and training at the time of the accident did not specifically require flight crews to cross-check the approach speed bug settings in relation to the ref speeds switch position; such awareness is important because a mismatch between the bugs and the switch could lead to an early stall warning. Therefore, the NTSB recommends that the FAA direct Part 121, 135, and 91K operators of airplanes equipped with a ref speeds switch or similar device to (1) develop procedures to establish that, during approach and landing, airspeed reference bugs are always matched to the position of the switch and (2) implement specific training to ensure that pilots demonstrate proficiency in this area.

Stall Training

During training for private and commercial certificates, pilots perform recoveries from fully developed stalls. Even though these stall recoveries are typically accomplished in small trainer-type airplanes, the sensations and lessons from this training usually remain with a pilot. However, as pilots transition to larger, autopilot-equipped, transport-category airplanes, they rarely, if ever, receive reinforcement of how actual stalls feel and how they are to be handled because air carrier training does not require pilots to practice recoveries from fully developed stalls.

The airline transport pilot practical test standards provide explicit guidance regarding how airline pilots should enter, induce, and recover from an impending stall (known as an approach to

[69] Colgan's ground school training included slides on ACARS and winter operations. However, specific information about entering icing terminology into ACARS and the relationship of these entries to the stall warning and the ref speeds switch were not discussed.

stall) but not a full aerodynamic stall. The approach-to-stall maneuvers require strict adherence to precise airspeed, altitude, and heading control and continuous smooth positive control. Colgan's training manual referenced the practical test standards in its procedures for stall training, and training records indicated that the accident pilots had met these standards during their Q400 training.[70]

The practical test standards currently require pilots to recover from an approach to stall with minimal altitude loss. This recovery procedure can be effective as long as an airplane is not fully stalled. However, altitude loss standards are not an appropriate method for determining if a pilot can recognize and properly respond to a fully developed stall. Once a stall has occurred, an airplane cannot be recovered until the wing's AOA is reduced, which will necessitate a loss of altitude. At stall AOAs, drag is high, and the thrust available may not be sufficient to overcome the drag. The nose of the airplane must be pitched down using the elevators. The amount of altitude loss during the recovery depends on several variables, including how slow the airplane is flying and how quickly the airplane is pitched down. Section 2.6.3.1 of the *Airplane Upset Recovery Training Aid* states, "to recover from a stall, angle of attack must be reduced below the stalling angle—apply nose down pitch control and maintain it until stall recovery."

Current air carrier training emphasizes the need to maintain altitude through the use of power during a stall recovery, and most turbine-powered aircraft can be flown nearly to a stall and recovered primarily with the application of full power (and pitch control inputs as required to counter any power-induced pitch changes). Colgan Q400 pilots indicated that, with approach-to-stall recoveries, the application of full power would typically require some nose-down pressure on the control column but that little change in pitch was required. The pilots stated that they were trained to use a balance of forward and aft column pressure to obtain the desired pitch during a recovery (rather than use a pronounced push forward) so that the airplane could regain a flying AOA and airspeed.[71]

Even though air carrier pilots are trained to use power to maintain altitude during approach-to-stall recoveries, positive nose-down control force is the necessary first step that a pilot must take once an actual aerodynamic stall has occurred. Because the application of power by itself will not recover a stalled airplane, approach-to-stall training may negatively affect a pilot's actions if a full stall were to develop. Although the accident captain responded as trained when he applied power in an apparent attempt to maintain altitude, he did not apply full power (the engine power levers were advanced to about 70°, but the rating detent was 80°), and he responded inappropriately to the stall warning by applying back pressure on the control column.

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[70] The captain's stall training at GIA was consistent with the training that he received at Colgan. The captain flew the Beech BE-1900D for GIA, and the BE-1900 AFM contained a warning to avoid the pitch excursions that can happen as power is increased during an approach-to-stall recovery. The stall profiles for the clean, takeoff, and landing configurations included the following comment: "With stall warning indication the aircraft will have approximately 10° nose up pitch. During recovery DO NOT lower or allow the nose to fall. Allow the aircraft to fly out of the stall."

[71] During Q400 simulator observations, the NTSB found that initial nose-up pitch attitudes of 7° to 10° were needed to recover from approaches to stalls with a minimal altitude loss compared with the greater nose-down pitch attitudes that are typically needed for stall recoveries in small trainer-type aircraft with the minimal loss of altitude appropriate for the airplane.

The NTSB identified three possible reasons related to Colgan's Q400 approach-to-stall simulator training to explain why he was apparently startled and confused by the stall warning. First, Colgan's simulator training did not include the use of the ref speeds switch set to the increase position. Thus, the training had not prepared the flight crew to recognize the early activation of the stick shaker as a result of the ref speeds switch being set to the increase position. Second, the simulator training was performed as a preplanned proficiency maneuver (the approach-to-stall maneuvers to be performed are well known by pilots in advance of their training) rather than as a maneuver with an element of surprise. However, a fully developed stall is an unplanned, emergency situation in which the airplane's nose must be pushed down to reduce the AOA. Third, the simulator training was hand flown by pilots. During the accident flight, the autopilot had been engaged until the onset of the stick shaker, at which time the autopilot disconnected automatically. Although autopilot disconnect needs to occur for a stall recovery maneuver to be accomplished, the captain (and the first officer) had not been trained to experience the sudden transition from automated to manual flight with an active stall warning.

The NTSB has investigated other accidents in which pilots applied inappropriate nose-up pitch control inputs during an attempted stall recovery. For example, on October 14, 2004, Pinnacle Airlines flight 3701, a Bombardier CRJ-200, was on a repositioning flight when the airplane stalled at 41,000 feet. FDR data showed that the flight crew moved the control column aft after the first stick shaker activation and moved the column aft with increasing magnitude after three subsequent activations of the stick pusher.[72]

Also, on December 22, 1996, an Airborne Express DC-8-63 was on a postmodification functional evaluation flight when it crashed in Narrows, Virginia.[73] The flight crew failed to apply positive nose-down control inputs in response to a stall at 14,000 feet. (The stall protection system was inoperative during the flight.) After the airplane stalled, the crew applied power to recover but did not establish nose-down control inputs.[74]

Another such accident involved West Caribbean Airways flight 708, an MD-82, near Machiques, Venezuela, on August 16, 2005. FDR data showed that the horizontal stabilizer reached its full nose-up position as the airplane descended from 31,000 feet. The CVR recorded the aural warning "stall, stall" and the continuous sound of the stick shaker for 1 minute 46 seconds before impact.[75]

The NTSB has continued to advocate for flight crew training in the post-stall flight regime because of multiple accidents in which flight crews did not apply appropriate recovery

[72] FDR data showed that the stick shaker activated five times and that the stick pusher activated four times.

[73] During the flight, a stall series was being performed to verify that the airspeeds at which the airplane experienced stick shaker activation and stall indication were in accordance with precalculated values for the airplane.

[74] For more information, see National Transportation Safety Board, *Uncontrolled Flight Into Terrain, ABX Air (Airborne Express), Douglas DC-8-63, N827AX, Narrows, Virginia, December 22, 1996*, Aircraft Accident Report NTSB/AAR-97/05 (Washington, DC: NTSB, 1997).

[75] The investigation of this accident is being conducted by the Comite de Investigación de Accidentes Aéreos of Venezuela.

procedures. For example, in a letter dated May 7, 2009, the NTSB commented on an NPRM titled, "Qualification, Service, and Use of Crewmembers and Aircraft Dispatchers," which proposed to amend the regulations for training programs for flight and cabin crewmembers and dispatchers. The NTSB indicated that stall recovery training should go beyond approaches to stall to include recoveries from a full stall condition and that available flight data from flight tests, accidents, and incidents should be used to model stall behavior to facilitate training beyond the initial stall warning.

If the approach-to-stall training that the flight crew received had been properly applied, then the crew should have recovered the airplane from the stall warning and the pitch excursion. However, the NTSB concludes that the current air carrier approach-to-stall training did not fully prepare the flight crew for an unexpected stall in the Q400 and did not address the actions that are needed to recover from a fully developed stall. Therefore, the NTSB recommends that the FAA require Part 121, 135, and 91K operators and Part 142 training centers to develop and conduct training that incorporates stalls that are fully developed; are unexpected; involve autopilot disengagement; and include airplane-specific features, such as a ref speeds switch.

Stick Pusher Training

The NTSB has investigated prior accidents in which pilots have responded incorrectly to the stick pusher. As previously indicated, the NTSB found that the flight crew of Pinnacle Airlines flight 3701 had responded to the stick pusher activations by pulling back on the control column, which caused the airplane to enter an aerodynamic stall. As a result, the NTSB issued Safety Recommendation A-07-4, which asked the FAA to do the following:[76]

> Convene a multidisciplinary panel of operational, training, and human factors specialists to study and submit a report on methods to improve flight crew familiarity with and response to stick pusher systems, and, if warranted, establish training requirements for stick pusher-equipped airplanes based on the findings of this panel.

On April 13, 2007, the FAA stated that it planned to ask the working group that developed the *Airplane Upset Recovery Training Aid* to reconvene and develop materials for this issue. On January 22, 2008, the NTSB classified this recommendation "Open—Acceptable Response."

In November 2008, the revised *Airplane Upset Recovery Training Aid* was published. However, the revised guidance does not explicitly address the need for, or methods to accomplish, stick pusher familiarization training. The NTSB is concerned that classroom training

[76] The NTSB notes that it issued a related safety recommendation, A-94-173, after the United Express flight 6291 accident. Safety Recommendation A-94-173 asked the FAA to "ensure that the training programs for 14 *Code of Federal Regulations* Part 135 pilots place an increased emphasis on stall warning recognition and recovery techniques, to include stick shaker and stick pusher, during training." The recommendation was classified "Closed—Acceptable Action" on November 14, 1995. For more information about the accident, National Transportation Safety Board, *Stall and Loss of Control on Final Approach, Atlantic Coast Airlines, Inc., United Express Flight 6291, Jetstream 4101, N304UE, Columbus, Ohio, January 7, 1994*, Aircraft Accident Report NTSB/AAR-94/07 (Washington, DC: NTSB, 1994).

of this important system is incomplete because the training does not familiarize pilots with the forces associated with stick pusher activation or provide them with experience in learning the magnitude of the airplane's pitch response. In addition, the FAA has not taken any other actions to meet the intent of Safety Recommendation A-07-4.

During the public hearing for this accident, a Bombardier test pilot stated that company pilots receive a stick pusher demonstration during training because pilots need to see and experience the tactile feel associated with the pusher's operation. Also, a NASA research scientist remarked that such training would help make the stick pusher's operation "somewhat less astonishing" if the pusher were to activate during flight, which could help in a situation similar to the one faced by the accident flight crew. The NTSB recognizes, however, that pusher familiarization training needs to be done correctly and provided in a context that does not lead to negative training.

When he flew the Saab 340, the captain received exposure to the stick pusher during ground checks before the first flight of the day,[77] and he might have received simulator training on the pusher. However, stick pusher training was not consistently provided to Colgan's Q400 pilots, and a check airman stated that about 75 percent of pilots who were shown the pusher in the simulator would try to recover by overriding the pusher. After the accident, the company implemented stick pusher familiarization training for its fleets.

The NTSB concludes that the circumstances of this and other accidents in which pilots have responded incorrectly to the stick pusher demonstrate the continuing need to train pilots on the actions of the stick pusher during flight and the airplane's initial response to the pusher. Therefore, the NTSB recommends that the FAA require all Part 121, 135, and 91K operators of stick pusher-equipped aircraft to provide their pilots with pusher familiarization simulator training. In addition, because the *Airplane Upset Recovery Training Aid* published in 2008 did not address the intent of Safety Recommendation A-07-4 and no other FAA action has met the recommendation's intent, Safety Recommendation A-07-4 is reclassified "Closed—Unacceptable Action/Superseded."

Simulator Fidelity

Flight training simulators contain computer-coded aerodynamic, engine, flight control, and other models to calculate the forces and moments on the airplane, which are then used to simulate the airplane's motion. The FAA's acceptance of flight training simulator devices had been guided by AC 120-40B, "Airplane Simulator Qualification," until May 30, 2008, when 14 CFR Part 60 became effective. Part 60 governs the initial and continuing qualification and use of flight simulation training devices and outlines the maneuvers and the tolerances to be used when comparing simulators and flight test time history data. According to Part 60, approval of full flight simulators (levels A through D) depends on passing a series of objective tests that compare the response of the simulator with the response of an airplane during a flight test.

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[77] First-flight-of-the-day checks are not substitutes for stick pusher familiarization training in a simulator. In addition, there may be negative transfer during these checks because of a tendency for pilots to hold some pressure against the pusher.

Part 60 applies more rigorous standards for all flight simulators than those described in AC 120-40B. For example, the regulation requires that full flight simulator stall characteristics be tested "for full stall and initiation of recovery." One of the simulator tests, "Stall Characteristics," states the following requirement, which must be met during the second segment climb, approach, or landing configuration:

> Time histories data must be recorded for full stall and initiation of recovery. The stall warning signal must occur in the proper relation to buffet/stall … FFSs [full flight simulators] of airplanes exhibiting a sudden pitch attitude change or 'g break' must demonstrate this characteristic.

The NTSB notes that the stall fidelity testing required under Part 60 is a significant improvement compared with the testing under AC 120-40B, which required only that the stall warning signal occur in the proper relation to stall. However, the NTSB also notes that Part 60 contains no bank tolerance requirement for speeds below stick shaker, no pitch tolerance requirement for any speed, and no requirements to address power-on or turning flight stalls.[78] In addition, because Part 60 applies only to simulators qualified after May 30, 2008, most training simulators currently in operation may not meet the regulation's requirements.

Flight crew training on full stalls and recoveries had not previously been included in simulator training partly because of industry concerns about the lack of simulator aerodynamic model fidelity in the post-stall flight regime. However, the NTSB believes that advances in technology can allow post-stall aircraft behavior to be modeled in simulators.

In the late 1990s, a government/industry commercial aviation safety team found that loss of control was among the top three causes of all worldwide fatal commercial aircraft accidents and was the second highest cause of passenger fatalities between 1988 and 1997. In its final report, the team identified several intervention strategies to reduce loss-of-control accidents,[79] including the following:

> To mandate stall recognition and recovery training, regulators must modify the appropriate regulations.
>
> Airlines/operators should develop and implement a ground school and simulator training program to train pilots to handle post stall recovery as part of advanced maneuver training.
>
> Regulators should mandate the implementation of a ground school and simulator training program to train pilots to handle post stall recovery as part of advanced maneuver training.

[78] The Part 60 requirements for stall characteristics are based on idle power, wings-level stalls at deceleration entry rates of 1 knot or less per second.

[79] Joint Safety Analysis Team, Loss of Control, Commercial Aviation Safety Team Approved Final Report, December 15, 2000.

The team's final report also noted, "several of the interventions address the need for upset recovery, stall and post-stall recovery training. To accomplish this training, improved aerodynamic modeling near the limits of the flight envelope (high angles of attack and/or sideslip)[80] is necessary for appropriate simulator fidelity."

In response to this work, NASA, along with Boeing, conducted a study beginning in the late 1990s to increase simulator model fidelity beyond the data envelope that existed at the time. This study used rotary balance and conventional wind tunnels to develop an aerodynamic model for the higher AOA and sideslip ranges that are required to simulate stall upsets in large transport-category airplanes. This enhanced upset recovery aerodynamic model was validated using certification flight test maneuver data, including stalls, and accident data. NASA and Boeing reported that simulations involving the enhanced upset recovery aerodynamic model were able to reasonably reproduce the results of stall flight tests, unlike the baseline simulation used in flight training at the time.

According to a 2005 paper that summarized findings from the NASA and Boeing study, this research demonstrated that simulation fidelity could be significantly improved and that the useful data envelope for upset training could be expanded. The paper concluded, "results from NASA/Boeing research conducted to date have led to a recommendation to re-examine the potential uses of simulators that are specifically designed for upset training. This research has demonstrated that simulation fidelity can be significantly improved such that the useful envelope for upset training may be expanded."[81]

Similarly, a 2009 paper on aerodynamic modeling for upset training concluded the following:

> Much work has been performed in the modeling and simulation of flight dynamics in 'extreme' conditions. Through this work, a process has been established that yields [a] model that [has] very good predictive capability and subsequent correlation with flight test data. Although most of the work in this area has focused on highly maneuverable military aircraft, the concepts for data collection and reduction are well suited for use in the civil arena, as was proven during two effort[s] sponsored by NASA in the past decade.[82]

In June 2009, the Royal Aeronautical Society[83] hosted a flight simulation conference, titled "Flight Simulation: Towards the Edge of the Envelope." Participants at the conference

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[80] Sideslip is the lateral angle between the longitudinal axis of the airplane and the direction of motion (flightpath or relative wind). Sideslip is normally produced by rudder forces, yawing motion resulting from asymmetrical thrust, or lateral gusts.

[81] J.V. Foster, K. Cunningham, et al., "Dynamics Modeling and Simulation of Large Transport Airplanes in Upset Conditions," American Institute of Aeronautics and Astronautics, Report No. AIAA-2005-5933, 2005.

[82] D.R. Gingras and J.N. Ralston, "Aerodynamic Modeling for Training on the Edge," *Proceedings of the Spring 2009 Flight Simulation Conference*, Royal Aeronautical Society, 2009.

[83] According to its website, the Royal Aeronautical Society, headquartered in London, England, is a multidisciplinary professional institution dedicated to the global aerospace community.

discussed the need for upset recovery training, training strategies, the role of motion cues in upset recovery training,[84] and aerodynamic modeling for upset recovery training. The aerodynamic modeling presentations indicated that extended envelope modeling (higher AOA and sideslip data ranges) was now possible for civil aircraft simulators and pointed out that military aircraft simulators already included such modeling.[85]

Also, a paper presented at the flight simulator conference indicated that Boeing was testing a higher-data-range simulator that incorporated lessons learned from the NASA and Boeing study.[86] According to the paper, several pilots who were tested in this higher-data-range simulator were typically able to complete upset training maneuvers without exceeding the simulator's validated flight envelope. Boeing's testing, however, did not evaluate pilot performance in upset recoveries with fully developed stall scenarios.

The NTSB notes that among the contributing causes to the Airborne Express/Narrows accident was the company's DC-8 flight training simulator's inadequate fidelity in reproducing the airplane's stall characteristics. Specifically, the stalls practiced by the flight crew in the training simulator resulted in a high sink rate at a nose-high attitude without the large roll excursions and uncommanded pitch-down experienced by the accident airplane. As a result, on July 29, 1997, the NTSB issued Safety Recommendation A-97-47, which asked the FAA to do the following:

> Evaluate the data available in the stall characteristics of airplanes used in air carrier service and, if appropriate, require the manufacturers and operators of flight simulators used in air carrier pilot training to improve the fidelity of these simulators in reproducing the stall characteristics of the airplanes they represent to the maximum extent that is practical; then add training in recovery from stalls with pitch attitudes at or below the horizon to the special events training programs of air carriers.

On June 9, 1999, the FAA stated that an aircraft in an aerodynamic stall might handle and perform differently than the programming in the simulator might indicate for an identical circumstance and that the acquisition of data in this flight condition would have questionable accuracy and would be costly and dangerous to acquire. On November 19, 1999, the NTSB stated that the ability of simulators to replicate an airplane's actions in some stall and stall recovery regimes could be improved and that the FAA's lack of action to improve simulator fidelity in reproducing stall characteristics was disappointing. As a result, Safety Recommendation A-97-47 was classified "Closed—Unacceptable Action."

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[84] Higher-level flight simulators consist of a simulated cab on a motion platform to provide pilots with onset motion cues. Such cues provide a vestibular/kinetic sense of the aircraft's motion, which is coupled with the motion of the visual scene.

[85] As a result of the conference, the Royal Aeronautical Society chartered an international committee for aviation training in extended flight envelopes. The committee's goals are to define best practices for upset recovery, training scenarios for these best upset recovery practices, and methods to validate simulator responses in training these scenarios.

[86] David C. Carbaugh, Robert A. Curnutt, et al., "Simulator Upset Recovery Training," *Proceedings of the Spring 2009 Flight Simulation Conference*, Royal Aeronautical Society, 2009.

As previously discussed, advances in post-stall modeling have occurred since the FAA's June 1999 response to Safety Recommendation A-97-47. However, during this and other accidents (including the Airborne Express/Narrows and the West Caribbean Airways flight 708 accidents), the pilots did not apply appropriate recovery controls after the airplane entered a sustained stall,[87] and the AOA might have exceeded the AOA validated for the full stall and initiation of recovery required by Part 60. In addition, statistics from the government/industry commercial aviation safety team for 1999 through 2008 showed that loss of control had become the leading cause of all worldwide fatal commercial aircraft accidents and the leading cause of passenger fatalities.

Operators should be aware of the possibility of negative effects when conducting stall training in flight regimes that exceed the validated flight envelope. If the full stall training requested in Safety Recommendation A-10-22 would be accomplished in a simulator, then it is essential that the simulator be approved for this training beyond the fully developed stall AOA. Simulator improvements to the high AOA flight characteristics will reduce the likelihood of negative training. The NTSB concludes that pilots could have a better understanding of an airplane's flight characteristics during the post-stall flight regime if realistic, fully developed stall models were incorporated into simulators that are approved for such training. Therefore, the NTSB recommends that the FAA define and codify minimum simulator model fidelity requirements to support an expanded set of stall recovery training requirements, including recovery from stalls that are fully developed. These simulator fidelity requirements should address areas such as required AOA and sideslip angle ranges, motion cueing, proof-of-match with post-stall flight test data, and warnings to indicate when the simulator flight envelope has been exceeded.

Tailplane Stall Training

The accident flight crew had seen a NASA-produced video, titled "Icing for Regional and Corporate Pilots," during winter operations training in initial, transition, and recurrent ground school. The video was intended to enhance a pilot's ability to assess hazardous icing conditions and understanding of icing effects on an airplane. The video also discussed tailplane stalls and wing stalls as a result of icing conditions. In addition, the video stated that pilots needed to properly diagnose icing problems (while maintaining airspeed awareness) because the differences between a wing and a tailplane stall were subtle but the recovery techniques were different.

The video indicated that tailplane stalls were most likely to occur with ice accumulation on the horizontal stabilizer and that symptoms of tailplane stalls included lightening of the controls, pitch excursions, difficulty in pitch trim, buffeting of the controls, and sudden nose-down pitching. The tailplane stall recovery procedure discussed in the video required pilots to pull back on the control column; reduce flap setting; and, for some aircraft, reduce power.

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[87] During a sustained stall, the airplane can reach AOAs beyond those that occur when an appropriate and a timely stall recovery technique is used. The flight characteristics of such sustained stalls are different from those of an unstalled airplane. Timely recognition of sustained stall characteristics could represent the last chance for a pilot to lower the AOA and recover the airplane.

However, the tailplane stall recovery procedure presented in the video was the opposite of the recovery procedure for a conventional wing stall, which requires lowering the nose and adding power.

Postaccident interviews with Colgan pilots about tailplane stalls produced varying responses. One captain stated that the video about tailplane icing made a big impression on him, and another captain stated that the video got his attention. Some pilots indicated that they would apply the tailplane stall procedure if they had clearly identified the symptoms of a tailplane stall, whereas other pilots stated that it would be difficult to determine if the airplane was in a conventional wing stall or a tailplane stall. Some pilots thought that the Q400 might be susceptible to a tailplane stall, some pilots were not sure about the airplane's susceptibility, and one pilot (a check airman) stated that the possibility of a tailplane stall in the Q400 had "never crossed [his] mind."

Colgan's manuals and training materials (except for the NASA icing video) made no reference to tailplane stalls or tailplane stall recovery techniques. Further, the company's director of flight standards indicated that the company did not teach pilots tailplane stall recovery techniques, and no procedures for tailplane stalls were included in the company's CFM or the Q400 AFM.

During the public hearing for this accident, officials from Bombardier testified that the Q400 was not susceptible to tailplane stalls. For example, the Bombardier principal engineering test pilot for the DHC-8 series stated that, during Q400 testing, the airplane showed no tailplane stall tendencies, and a Bombardier engineering manager stated that the company did not have a tailplane stall recovery procedure because the airplane was demonstrated to be free from tailplane stalls under all conditions. The engineering manager also stated that he was not aware of any formal document to Q400 operators indicating that the airplane was not susceptible to tailplane stalls.

Also during public hearing testimony, the FAA's manager of air carrier training stated his belief that no airplanes currently being operated by Part 121 air carriers were susceptible to tailplane stalls. He recalled that the early versions of two airplanes, the Saab 340 and the Jetstream J31, had tailplane stall tendencies but stated that these tendencies were corrected by airworthiness directives and manufacturing changes. The FAA manager further indicated that training programs should not lead to negative training or possible miscues regarding how flight crews are to handle a full wing stall.

It is unlikely that the captain was deliberately attempting to perform a tailplane stall recovery in response to the stick shaker activation. Nevertheless, the NTSB concludes that the inclusion of the NASA icing video in Colgan Air's winter operations training may lead pilots to assume that a tailplane stall might be possible in the Q400, resulting in negative training. Therefore, the NTSB recommends that the FAA identify which airplanes operated under Part 121, 135, and 91K are susceptible to tailplane stalls and then (1) require operators of those airplanes to provide an appropriate airplane-specific tailplane stall recovery procedure in their training manuals and company procedures and (2) direct operators of those airplanes that are not susceptible to tailplane stalls to ensure that training and company guidance for the airplanes explicitly states this lack of susceptibility and contains no references to tailplane stall recovery procedures.

Federal Aviation Administration Oversight

Oversight of the Colgan certificate and the Q400 program were provided by a POI and a Q400 APM. The POI was based at the Washington FSDO, which was near the company's headquarters at the time of the accident, and the Q400 APM was based at the Teterboro FSDO, which was near the EWR base. The investigation of this accident found that FAA records of oversight activities at Colgan showed no deficiencies related directly to the circumstances of the accident.

The investigation also found that, between February 2007 and February 2008, Colgan underwent a period of substantial growth. During this time, the Q400 was introduced into the company's operations, a relatively large number of pilots ("a couple of hundred," according to the company's vice president of administration) was hired, and a new Q400 base of operations was established at EWR.[88] In addition, Colgan had to outsource Q400 flight crew training (with FlightSafety International in Toronto, Canada) until the company could become fully qualified to conduct its own Q400 flight crew training (which occurred in July 2008).

FAA Order 8900.1, "Flight Standards Information Management System," notes that POIs must determine when surveillance retargeting is required based on, among other things, significant changes in an air carrier's operating environment, including changes in the scope and scale of operations (that is, growth or downsizing).[89] The order indicated that such changes could affect a carrier's ability to balance its resources, size, and organizational structure with operational requirements. The investigation of this accident did not find any evidence that surveillance retargeting had occurred. For example, no evidence showed that the size of the certificate management team changed despite the significant growth that Colgan was experiencing. The POI stated, during a postaccident interview, that the only other aviation safety inspector on his staff (besides the Q400 APM) was an APM for the Saab 340.

Also, neither the POI nor the previous Q400 APM (who was in the position from March 2007 to February 2008) was qualified on the Q400 at the time that it was initially incorporated into Colgan's fleet. The POI received his Q400 training in October and November 2007, which was the same time that Colgan line pilots were being initially trained on the airplane. Also, he and the previous APM were responsible for overseeing proving flights[90] for the Q400, even though they were not completely familiar with the airplane. The current Q400 APM was assigned

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[88] The 15 Q400 airplanes that Colgan purchased and the pilots hired to fly the airplanes represented about a 30-percent increase in the size of the company.

[89] FAA Order 8900.1 also states that surveillance retargeting is required for other triggering events, such as accidents or incidents.

[90] Before revenue service can be operated, proving flights have to be conducted as part of compliance with a new aircraft process document, which directs the activities and provides guidance for aviation safety inspectors during the addition of a new aircraft make and model to an air carrier's operations.

to the certificate in March 2008, after Q400 revenue service had begun, and received his Q400 training in May 2008. Although both FAA aviation safety inspectors were experienced pilots, they were responsible for overseeing the newly introduced service of an airplane for which they were not previously qualified and had not flown except during simulator training. As a result, the inspectors had to continue to become familiar with the airplane while they were conducting their day-to-day management of the certificate.

In December 2009, Colgan moved its headquarters from the Washington, D.C., area to Memphis, but the Colgan certificate remained with the Washington FSDO. Thus, the POI is providing oversight of operations at Colgan headquarters and the company's training center (also located in Memphis) from a remote location. However, during its investigation of the December 2007 Air Wisconsin Airlines flight 3758 accident in Providence, Rhode Island, the NTSB found that providing remote oversight was difficult for the company's POI, assistant POI, and APM, who were not located near the company's primary training center and crew bases.[91]

FAA Order 8900.1 also states that rapid expansion or growth of an air carrier could affect its training programs. In October 2007, during Colgan's rapid growth period, the captain was disapproved for a Saab 340 airline transport pilot certificate and type rating on his initial attempt to upgrade to captain. (He received the airline transport pilot certificate and type rating later that month on a subsequent attempt.) This disapproval was the captain's second failed checkride since beginning work for Colgan; he had also been previously graded "train to proficiency" during another checkride. Because of his continued weaknesses in basic aircraft control and attitude instrument flying, the captain was a candidate for remedial training. However, the POI did not recommend that the company provide remedial or another type of supplemental training to the captain or other pilots with persistent training deficiencies, even though SAFO 06015, issued in 2006, recommended the implementation of such training. (During the public hearing for this accident, the POI for Colgan stated that he was not aware of the SAFO.)

Even though Colgan's training and checking programs were approved by the FAA, the FAA aviation safety inspectors could only conduct a small number of the training and checking events at the airline because of their other responsibilities. As a result, the inspectors had to rely on company aircrew program designees (under the aircrew designated examiner program) for airline transport pilot certifications and type ratings and check airmen for proficiency and line checks. The POI was responsible for operations within the aircrew designated examiner program, and the Q400 APM supported the POI by providing surveillance of program activities associated with that specific airplane type. The APM was also responsible for recommending candidate aircrew program designees to the POI, who made the selections, and for qualifying each designee in the conduct of airman certification. In addition, the APM was responsible for overseeing check airmen and ensuring that they maintained high standards when conducting proficiency and line checks.

[91] The inspectors were located in Chicago, Illinois; the company's primary training center was located in Charlotte, North Carolina; and the crew bases were in Philadelphia, Pennsylvania, Washington, D.C., and Norfolk, Virginia.) Additional information about this accident, NTSB case number DCA08FA018, is available on the NTSB's website.

FAA Order 8900.1 further states, “air carrier expansion or growth can also raise potential safety and quality concerns, and influence the likelihood of noncompliance with existing processes and controls.” Because of the 15 new Q400 airplanes in its inventory, Colgan needed to upgrade pilots to Q400 captains and train newly hired (and low-time) pilots as Q400 first officers. This situation warranted additional FAA oversight of Colgan’s check airmen and aircrew program designees to ensure that training and checking standards were not affected by pressures to qualify these pilots. The NTSB notes that this focused oversight was also needed because of the lack of detail in Colgan’s electronic pilot training records and the lack of previous Part 121 experience of some company Q400 check airmen and aircrew program designees.[92] Available Q400-qualified aviation safety inspectors from all FAA regions and from Part 142 training centers could have augmented the certificate’s inspectors and provided quality assurance over Colgan’s aircrew program designees.

In addition, the International Air Transport Association (IATA) and the Department of Defense (DOD) conducted independent audits of Colgan in 2007. Both of the audits contained findings that necessitated corrective actions by Colgan. The corrective actions taken by Colgan in response to the audit findings were accepted by IATA in September 2007 and DOD in April 2008. The Colgan POI stated that he was aware of these audits but did not get a copy of the reports, which prevented him from having a comprehensive understanding of the reports’ findings. For example, the POI believed that IATA’s findings were minor[93] and that a DOD issue was not within the scope of his responsibilities because it was not mandated by the FAA.

One finding from the audits involved Colgan’s internal evaluation program (IEP),[94] which is not required by FAA regulations. As previously stated, the NTSB found significant problems with Colgan’s pilot training records. These problems would likely have been prevented by a sound IEP, which did not exist at the time of the audits and during Colgan’s period of rapid growth.[95] However, the issues with Colgan’s IEP were subsequently corrected to the satisfaction of the auditing organizations. Although the NTSB recognizes that the POI needed to perform his duties in accordance with stated regulations and procedures, use of evaluation tools, such as these audits, might have alerted him to items that required close review.

On December 20, 1996, the NTSB issued Safety Recommendation A-96-163 as a result of its investigation of the December 1995 Tower Air flight 41 accident in Jamaica, New York.[96] Safety Recommendation A-96-163 asked the FAA to do the following:

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[92] After the accident, the NTSB interviewed five company Q400 check airmen and two company Q400 aircrew program designees. The NTSB learned that none of the check airmen or aircrew program designees had any previous Part 121 experience before their employment with Colgan.

[93] The NTSB has made no determination to characterize the audit findings.

[94] As stated in AC 120-59, “Air Carrier Internal Evaluation Programs.” IEPs are voluntary self-monitoring and auditing programs adopted by most Part 121 air carriers.

[95] At that time, the program was in its early stages of development.

[96] For more information, see National Transportation Safety Board, *Runway Departure During Attempted Takeoff, Tower Air Flight 41, Boeing 747-136, N605FF, JFK International Airport, New York, December 20, 1995*, Aircraft Accident Report NTSB/AAR-96/04 (Washington, DC: NTSB, 1996).

> Develop, by December 31, 1997, standards for enhanced surveillance of air carriers based on rapid growth, change, complexity, and accident/incident history; then revise national flight standards surveillance methods, work programs, staffing standards, and inspector staffing to accomplish the enhanced surveillance that is identified by the new standards.

On November 24, 2004, the NTSB stated that the FAA had briefed NTSB staff in March 2004 about programs related to oversight and surveillance of air carriers, including the air transportation oversight system (ATOS) and the Surveillance and Evaluation Program.[97] The NTSB indicated that, during this briefing, the FAA had stated that the risk indicators used by the Surveillance and Evaluation Program for targeting surveillance resources included rapid growth or expansion, new or major program changes, complexity of aircraft or new aircraft types, and accident and incident history. Because the FAA had developed these surveillance standards, the NTSB classified Safety Recommendation A-96-163 "Closed—Acceptable Action."

Since that time, the NTSB has investigated several accidents in which inadequate FAA oversight was a factor and issued several recommendations to address these inadequacies. For example, Safety Recommendation A-05-8, issued as a result of the Air Sunshine flight 527 accident, asked the FAA in part to review the procedures used during its oversight of the company, including those for the Surveillance and Evaluation Program, to determine why the inspections failed to ensure that the operational and maintenance issues that existed at the company were corrected.[98]

Colgan's substantial growth came at a time when the air carrier was transitioning from, according to the Q400 APM, a "mom and pop," or startup, airline. Also, the POI for Colgan stated that the safety culture at the company was "more reactive than I'd like … not quite as proactive." As a result, additional resources for enhanced FAA oversight of the certificate were needed but were not provided. This situation is problematic because, according to a Pinnacle Airlines third quarter 2009 financial report, 30 additional Q400s have been ordered for Colgan (15 of which will be delivered beginning in 2010), continuing the company's expansion and rapid growth.

A June 2005 report by the Department of Transportation's Office of Inspector General found that, at five Part 121 air carriers that were experiencing rapid growth, FAA inspectors were not able to effectively use oversight systems (ATOS and the Surveillance and Evaluation Program) to monitor the rapidly occurring changes.[99] The NTSB concludes that the current FAA surveillance standards for oversight at air carriers undergoing rapid growth and increased complexity of operations do not guarantee that any challenges encountered by the carriers as a result of these changes will be appropriately mitigated. Therefore, the NTSB recommends that

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[97] According to the FAA, as part of the Surveillance and Evaluation Program, tools were developed for principal inspectors to assess the overall risk situation of a carrier, document and analyze their observations, and refocus the surveillance program toward those areas for which the highest risks were perceived.

[98] Safety Recommendation A-05-8 was classified "Closed—Acceptable Action" on August 27, 2009.

[99] Department of Transportation, *Safety Oversight of an Air Carrier Industry in Transition*, Report Number AV-2005-062 (Washington, DC: DOT/OIG, 2005).

the FAA develop more stringent standards for surveillance of Part 121, 135, and 91K operators that are experiencing rapid growth, increased complexity of operations, accidents and/or incidents, or other changes that warrant increased oversight, including the following: (1) verify that inspector staffing is adequate to accomplish the enhanced surveillance that is promulgated by the new standards, (2) increase staffing for those certificates with insufficient staffing levels, and (3) augment the inspector staff with available and airplane-type-qualified inspectors from all FAA regions and Part 142 training centers to provide quality assurance over the operators' aircrew program designee workforce.

Company Policies

Flight Operational Quality Assurance

Flight operational quality assurance (FOQA) is a voluntary safety program in which an air carrier collects, deidentifies, and analyzes actual in-flight data from a quick access recorder (QAR)[100] or an FDR to identify potential operational risks and implement corrective actions. According to the FAA, as of October 30, 2009, 19 of the 82 Part 121 certificate holders had FAA-approved FOQA programs.[101] Although Colgan had received FAA approval for its FOQA implementation and operations plan in October 2008, the FOQA program was not fully implemented and was not providing useful information at the time of the accident. The FAA manager for voluntary safety programs reported that FOQA implementation could take about 1 year and that Colgan's implementation efforts were hindered by unanticipated issues affecting the installation of FOQA hardware. In October 2009, Colgan stated that QAR data analysis was projected to begin by the end of January 2010.

Colgan's voluntary reporting systems, including the aviation safety action program (ASAP), did not include any reports of stall warnings. However, it is possible that a stall warning resulting from a mismatch between the ref speeds switch and the airspeed bugs may be a more common occurrence than currently realized, given the circumstances of the accident flight and the BTV event. The frequency and circumstances of stall warnings could be examined as part of a FOQA program because, in developing FOQA programs, operators select the recorded flight parameters to be analyzed and one available parameter is the in-flight activation of the stall warning system.[102] Any information learned from analysis of FOQA program data could result in

[100] QARs are recording units installed on aircraft to store data recorded during flight. The recorders provide quick and easy access to a removable medium, such as an optical disk or personal computer memory card, on which the flight information is recorded. According to the FAA, QARs have been developed to record an expanded data frame; some of the recorders support more than 2,000 parameters at higher sample rates than FDRs.

[101] FOQA programs are not required to be approved by the FAA. However, an advantage of having an FAA-approved FOQA program is participation in the FAA's Aviation Safety Information Analysis and Sharing (ASIAS) system. According to the FAA's director of aviation safety analytical services, ASIAS is a government-industry partnership that brings together safety information in a protected forum, allowing queries and analysis of multiple databases. This director stated that, as of July 2009, 21 air carriers with FAA-approved FOQA programs were participating in ASIAS. Although ASIAS has been used to analyze events such as tail strikes and wrong runway departures, it has not yet been used to analyze stick shaker or stall warning events.

[102] The accident airplane's FDR recorded stick shaker and stick pusher parameters once every 4 seconds. In contrast, a QAR might be designed to record hard-target FOQA parameters at higher sample rates to yield a high-confidence analysis of stall warning events in the Q400 fleet.

revised company procedures, checklists, and training and could be shared with the FAA and others in the aviation industry.

Even though Colgan did not have a functioning FOQA program at the time of the accident, the company might have benefited from other air carriers' information about the Q400, including stall warnings. However, the two other U.S. operators of the Q400 are both regional airlines without FOQA programs.

Most of the operators with FOQA programs were established major airlines, which had a significant amount of data about the operation of the aircraft in their fleet. At the time of the accident, the FAA made no systematic attempt to determine whether newer or smaller airlines, including regional airlines, were participating in FOQA programs and whether newer aircraft, including the Q400, were included in FOQA data monitoring efforts.

Not all airplanes are capable of supporting a FOQA data recording. Those airplanes that are currently able to support these recordings are equipped with a data bus that allows information to be transmitted in digital format from multiple data sensors to QARs. The FAA has not done a survey of the Part 121 air carrier fleet to determine how many airplanes are QAR capable. However, operators of those airplanes that are capable of supporting a QAR recording might still need a supplemental type certificate for a QAR retrofit, which could be expensive and time-consuming. Some new aircraft have QAR capability already installed, so the process to implement a FOQA program could be greatly simplified for operators of these airplanes.

On January 23, 2007, the NTSB issued Safety Recommendation A-07-11, which asked the FAA to strongly encourage and provide assistance to all regional air carriers to implement an approved ASAP and a FOQA program. On April 13, 2007, the FAA stated that it took several actions in response to this recommendation, including participation at Regional Airline Association conferences to increase awareness of ASAP and FOQA and the issuance of AC 120-92, "Introduction to Safety Management Systems for Air Operators," which identified FOQA as an integral part of a safety management system (SMS). As a result of these actions, Safety Recommendation A-07-11 was classified "Closed—Acceptable Action" on January 22, 2008.

Also in its response to Safety Recommendation A-07-11, the FAA recognized that there was significant participation in ASAP among regional operators but that only a few regional operators participated in FOQA. The recommendation asked the FAA to "strongly encourage" regional air carriers to voluntarily implement a FOQA program, yet only three regional airlines had FOQA programs either planned or underway as of July 2009.

As indicated in AC 120-82, "Flight Operational Quality Assurance," FOQA programs provide objective safety information that would not otherwise be obtainable. Also, FOQA was established as a worldwide standard by International Civil Aviation Organization in 2005, but U.S. air carriers are not required to conform with this standard because FOQA is currently a voluntary program. During his December 2009 testimony before the U.S. Senate, the FAA Administrator stated that he had asked operators without a FOQA program to implement this program and develop data analysis processes to ensure effective use of program information. The NTSB concludes that mandatory FOQA programs would enhance flight safety because all operators would have readily available data to identify operational risks and use in developing corrective actions. Therefore, the NTSB recommends that FAA require all Part 121, 135, and 91K operators to (1) develop and implement FOQA programs that collect objective flight data, (2) analyze these data and implement corrective actions to identified systems safety issues, and (3) share the deidentified aggregate data generated through these analyses with other interested parties in the aviation industry through appropriate means.

The NTSB recognizes that, as indicated in AC 120-82, FOQA is built upon the provisions of 49 *United States Code* 40123 and 14 CFR Part 193, which establish protection of voluntarily submitted information. The FAA states in AC 120-82 that maintaining confidentiality of FOQA information among operators is important for providing a cooperative environment. If FOQA data were required to be provided to the FAA, these data would no longer fall under the protections provided by 49 *United States Code* 40123 and 14 CFR Part 193. The NTSB concludes that the viability of FOQA programs depends on the confidentiality of the data, which would currently not be guaranteed if operators were required to implement these programs and were required to share the data with the FAA. Therefore, the NTSB recommends that the FAA seek specific statutory and/or regulatory authority to protect data that operators share with the FAA as part of any FOQA program.

In addition, Colgan had previously proposed including, as part of its FOQA program, a sample of CVR recordings from routine line operations. The company indicated that the sample CVR recordings could be used to determine, among other information, how well pilots adhered to sterile cockpit and standard operating procedures, which could help to prevent accidents. The company asserted that its use of the CVR for FOQA purposes would ensure pilots' confidentiality.

The NTSB has recognized the benefits of using flight recorder information for safety purposes. For example, on October 1, 2009, the NTSB issued Safety Recommendation A-09-99, which asked helicopter emergency medical services operators to "establish a structured flight data monitoring program that incorporates routine reviews of all available sources of information to identify deviations from established norms and procedures and other potential safety issues." Aircraft operators would benefit from similar reviews of available safety information sources that are downloaded as part of a company's FOQA program. The NTSB concludes that the systematic monitoring of all available safety data, as part of a flight operational quality assurance program, could provide operators with objective information regarding the manner in which flights are conducted and that a periodic review of this information would enhance flight safety by assisting operators in detecting and correcting deviations from standard operating procedures. Therefore, the NTSB recommends that the FAA require Part 121, 135, and 91K operators to (1) routinely download and analyze all available sources of safety information, as part of their FOQA program, to identify deviations from established norms and procedures; (2) provide appropriate protections to ensure the confidentiality of the deidentified aggregate data; and (3) ensure that this information is used for safety-related and not punitive purposes.

Use of Personal Portable Electronic Devices on the Flight Deck

The NTSB has identified hazards associated with the use of mobile phone technology (including texting) in rail and highway accidents and has issued recommendations to restrict the use of this technology by transport operators.[103] Also, in 2008, the NTSB added, to its Most Wanted List, the need to restrict cellular telephone use by commercial drivers of school buses and motorcoaches, except in emergencies.

During the taxi phase of the accident flight, the first officer sent a text message on her personal cell phone about 2113, which was about 5 minutes 30 seconds before air traffic control (ATC) cleared the flight for takeoff. (Evidence indicated that the airplane was not moving at the time that she used her mobile phone.) However, AC 91.21-1B, "Use of Portable Electronic Devices Aboard Aircraft,"[104] which was issued on August 25, 2006, indicated that cell phones were not to be used while an aircraft was taxiing for departure after leaving the gate. The AC further stated that cell phones should be turned off and properly stored so that the aircraft could be prepared for takeoff. Although Colgan's policy on the use of mobile phones on the flight deck was consistent with the guidance contained in AC 91.21-1B, the company's pilot checklists did not address turning off cell phones in preparation for departure. Colgan also stated that it considered the use of cell phones by flight crewmembers to be covered as part of sterile cockpit procedures.

On February 4, 2009, the FAA published SAFO 09003, "Cellular Phone Usage on the Flight Deck." The purpose of this SAFO was to alert all Part 121 and 135 operators to the potential hazards associated with flight crewmembers leaving their cellular phones on during critical phases of flight. The SAFO was the result of an inspector's observation of a ring tone/warbling sound coming from a first officer's cellular phone during a takeoff roll just before reaching the airplane's takeoff decision speed. The SAFO stated that the ring tone was a distraction to the flight crew and could have resulted in an unnecessary rejected takeoff. The FAA found that the company's guidance did not prohibit flight crewmembers from leaving phones on while on the flight deck and that the company's checklists did not address turning off cell phones in preparation for departure.

[103] For example, on November 30, 2006, the NTSB issued Safety Recommendation H-06-27, which asked the Federal Motor Carrier Safety Administration to "publish regulations prohibiting cellular telephone use by commercial driver's license holders with a passenger-carrying or school bus endorsement, while driving under the authority of that endorsement, except in emergencies." The recommendation is currently classified "Open—Acceptable Response." Also, on June 13, 2003, the NTSB issued Safety Recommendation R-03-1, which asked the Federal Railroad Administration to "promulgate new or amended regulations that will control the use of cellular telephones and similar wireless communication devices by railroad operating employees while on duty so that such use does not affect operational safety." The recommendation was classified "Closed—Acceptable Alternate Action" on September 17, 2009.

[104] According to the AC, portable electronic devices are personal devices that include, for example, mobile telephones; computers with wireless network capabilities; and other wireless-enabled devices, such as personal digital assistants. Such devices are not provided by an operator for use in supporting flight operations. Electronic flight bags or laptop computers used for landing performance calculations would thus not be considered personal portable electronic devices.

The SAFO recommended that directors of operations of all Part 121 and 135 certificate holders review guidance to determine if procedures are in place to remind flight crews to turn off phones while on the flight deck. The SAFO also recommended a review and evaluation of the operator's indoctrination and recurrent training curriculums concerning cell phone use and the sterile cockpit concept.

On October 21, 2009, Northwest Airlines flight 188, an Airbus A320, N374NW, became a "NORDO" (no radio communications) flight at 37,000 feet. The flight was operating under 14 CFR Part 121 from San Diego, California, to Minneapolis-St. Paul International/Wold-Chamberlain Airport (MSP) with 5 crewmembers and 144 passengers on board. The flight was NORDO for about 1 hour 17 minutes. During that time, the airplane flew past MSP and continued northeast for about 100 miles. When the flight crew and the MSP center controller reestablished communications, the first officer stated, "we got distracted and we've overflown MSP. We are overhead Eau Claire [Wisconsin] and would like to make a 180 [degree turn] and do an arrival from Eau Claire." About 5 minutes later, the controller asked the first officer to explain what had caused the situation, and he replied, "just cockpit distraction, that's all I can tell you."

During interviews with the Northwest flight crew, the NTSB learned that the distraction involved the use of personal laptop computers during the discussion of new flight crew scheduling software and procedures. However, Delta Air Lines policy (which governed Northwest operations as a result of a merger with the company), prohibited the use of personal computers and other personal electronic devices on the flight deck.[105]

Although the Colgan first officer's use of her personal cell phone during the taxi phase of the accident flight was not directly associated with the accident, the event described in SAFO 09003 illustrates the potential for such devices to create a hazardous distraction during a critical phase of flight. In addition, the Northwest event showed that the use of a personal computer during cruise flight could severely affect flight crew situational awareness. The NTSB concludes that distractions caused by personal portable electronic devices affect flight safety because they can detract from a flight crew's ability to monitor and cross-check instruments, detect hazards, and avoid errors. Therefore, the NTSB recommends that the FAA require all Part 121, 135, and 91K operators to incorporate explicit guidance to pilots, including checklist reminders as appropriate, prohibiting the use of personal portable electronic devices on the flight deck.

Safety Alerts for Operators

According to FAA Order 8000.87A, SAFOs "contain important safety information that is often critical." SAFOs are intended for FAA inspectors; air carrier directors of safety, operations, and maintenance; fractional ownership program managers; training center managers; repair station managers; and others as applicable. Although FAA inspectors are among the intended audience, the order states, "SAFOs do not burden FAA inspectors with additional responsibilities not included in their work programs and not processed in accordance with the agreement between

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[105] For more information about this incident, see DCA10IA001 on the NTSB's website.

the FAA and its inspectors' bargaining unit." At the public hearing for this accident, the FAA's manager of air carrier operations asserted that this language was included in the order because FAA inspectors are heavily tasked.

As previously noted, the FAA had issued SAFOs concerning issues identified in this investigation, including SAFO 06004, "Approach and Landing Accident Reduction: Sterile Cockpit, Fatigue," dated April 28, 2006, and SAFO 06015, "Remedial Training for Part 121 Pilots," dated October 27, 2006. The recommended actions discussed in these SAFOs included increased emphasis on sterile cockpit discipline, fatigue countermeasures and operator fatigue management, and additional training and oversight for pilots who have experienced multiple training and checking failures. FAA Order 8000.87A stated that operators are responsible for implementing the actions recommended in a SAFO. However, no evidence showed that Colgan had initiated any of the recommended actions in these SAFOs.

The FAA does not routinely track whether the recommended actions included in SAFOs have been adopted,[106] citing inspector workload as a reason. The FAA order states that SAFOs are "especially valuable" to air carriers in meeting their statutory duty to operate with the highest degree of safety. The NTSB recognizes the importance of an air carrier's statutory responsibility to provide safe transportation. However, the FAA has a statutory responsibility to provide effective oversight of the aviation industry. Assessing an operator's need to implement action on "important safety information that is often critical" and measuring the resulting change is an inherent responsibility of FAA inspectors and must be considered part of their workload. Delegating the responsibility for these actions solely to an operator may not produce the desired outcome.

SAFOs may be an appropriate method for disseminating routine or initial information to operators in a timely manner. However, when safety-critical information, which often requires a change in industry practices or procedures, needs to be distributed, SAFOs are not the appropriate format because no requirement exists for the FAA to measure whether the SAFO achieved its intended result. The FAA uses an SMS approach to structure its oversight processes, but transmitting critical safety information to operators without measuring results is inconsistent with the basic principles of this system.

The FAA's manager of air carrier operations testified at the public hearing that the agency was considering the establishment of a new transmittal method for safety-critical information, referred to as an operational directive, which would be similar to an airworthiness directive. Thus, operators would be responsible for complying with the operational directive, and FAA inspector surveillance would be required to determine whether the recommended actions had been accomplished. The NTSB is encouraged that the FAA is considering this new method for transmitting safety-critical information. The same safety benefit could be achieved if the FAA revised Order 8000.87A so that the SAFO process would incorporate FAA followup. The NTSB

[106] The FAA has undertaken tracking efforts for some SAFOs to determine whether the desired safety benefit has been realized. For example, FAA Notice 8900.71 was issued on April 23, 2009, in response to the NTSB's March 2009 request for an assessment of industry actions taken in response to SAFOs 06015 and 06005 (the latter of which discussed bounced landing training).

concludes that the current use of SAFOs to transmit safety-critical information is not effective because oversight and documentation of an operator's response are not required and critical safety issues may not be effectively addressed. Therefore, the NTSB recommends that the FAA implement a process to document that all Part 121, 135, and 91K operators have taken appropriate action in response to safety-critical information transmitted through the SAFO process or another method.

Preflight Weather Documents and Icing Terminology

No evidence showed that the icing conditions that existed before the accident were abnormal for wintertime operations in the BUF area. However, the NTSB's investigation of this accident identified two weather-related safety issues—preflight weather documents provided to Part 121 flight crews and icing terminology used in the *Aeronautical Information Manual* (AIM)—that warranted changes.

Preflight Weather Documents

Chapter 26 of FAA Order 8900.1, Aviation Weather Information Systems for Air Carriers, section 3-2094, "Operational Requirements—Flightcrews," states the following regarding weather information provided to flight crews:

> Flightcrews need accurate weather information to determine the present and forecast weather conditions on any planned operation. For example, for adequate flight planning, flightcrews should know existing and expected weather conditions at the departure airport, along the planned route of flight, and at destination, alternate, and diversionary airports.

The section also provides a list of the numerous weather products that flight crews need to consider in operational preflight planning decisions.

Chapter 26 of the order, section 3-2096, "Adverse Weather Phenomena Reporting and Forecasting Requirements,"[107] states that any weather information system used in Part 121 operations must include an FAA-approved adverse weather phenomena reporting and forecasting subsystem. Such subsystems allow operators to monitor weather reports from various sources to quickly and accurately identify adverse weather phenomena and predict their effects on flight and ground operation safety. The subsystems are required to include forecasting capabilities that are at least equal to those of government weather forecasting systems.[108] Even though the subsystems are automated, dispatch personnel are responsible for (1) programming the subsystems to ensure

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[107] According to section 3-2096, adverse weather phenomena are meteorological conditions that could affect safety if encountered during flight or ground operations. Examples of such phenomena include surface winds exceeding 30 knots, active thunderstorms, moderate or severe in-flight icing, severe or extreme turbulence, and meteorological conditions causing runway surface contamination.

[108] According to 14 CFR 121.101, "each certificate holder conducting domestic or flag operations shall adopt and put into use an approved system for obtaining forecasts and reports of adverse weather phenomena, such as clear air turbulence, thunderstorms, and low altitude wind shear, that may affect safety of flight on each route to be flown and at each airport to be used."

that they capture specific weather products during specific time periods for the arrival and alternate airports for each flight and (2) providing weather documents containing this information to flight crews. In this case, the Colgan director of dispatch was responsible for programming the company's FAA-approved private weather contractor subsystem to capture specific weather products for the route of flight between EWR and BUF (and from EWR to Greater Rochester International Airport, Rochester, New York, the alternate airport).

The weather document for the accident flight was issued about 1800. The NTSB's review of this document revealed that it was missing pertinent information. For example, the weather document did not contain relevant Airmen's Meteorological Information advisories (AIRMETs),[109] even though they are among the in-flight weather advisories that flight crews need to determine present and forecast weather conditions for an operation. One of the missing AIRMETs relevant to the accident flight extended over the flight route and alerted pilots to expect moderate rime icing below 8,000 feet. Another missing and relevant AIRMET extended over a larger region in the northeast, including the accident site, and alerted pilots to expect occasional moderate icing below 18,000 feet. The icing conditions in both of these AIRMETs were expected to last from 2145 to 0400 the next day.[110] The NTSB's investigation of this accident verified the conditions detailed in the AIRMETs.

The only icing information included in the weather document for the accident flight was the reports and forecast of snow at BUF and two pilot reports (PIREP) indicating light-to-moderate rime icing in the BUF area between 3,000 and 14,000 feet. Even though the minimal aircraft performance degradation resulting from ice accumulation did not affect the flight crew's ability to fly and control the airplane, the NTSB is concerned that pertinent preflight information regarding icing along the flight route was not relayed to the crew. The AIRMETs relevant to the accident flight that were not included in the weather document would have provided the crew with additional information about icing and, accordingly, would have increased situational awareness. However, this increased situational awareness would not likely have affected the outcome of the flight.

On August 15, 1996, the NTSB issued Safety Recommendation A-96-48 as a result of its investigation of the American Eagle flight 4184 accident in Roselawn, Indiana.[111] Safety Recommendation A-96-48 recognized the importance of AIRMETs and Center Weather Advisories (CWAs)[112] in flight planning and asked the FAA to do the following:

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[109] An AIRMET is one of five weather advisory categories used by the National Weather Serivce to inform pilots of significant weather phenomena. The other categories are Severe Weather Forecast Alerts, Significant Meteorological Information (SIGMETs), Convective SIGMETs, and Center Weather Advisories.

[110] Other AIRMETs in effect at the time described instrument flight rules conditions and turbulence over the BUF area. These AIRMETs were also not included in the weather document.

[111] For more information, see National Transportation Safety Board, *In-flight Icing Encounter and Loss of Control, Simmons Airlines, d.b.a. American Eagle Flight 4184, Avions de Transport Regional (ATR) Model 72-212, N401AM, Roselawn, Indiana, October 31, 1994*, Aircraft Accident Report NTSB/AAR-96/01 (Washington, DC: NTSB, 1996).

[112] A CWA is an aviation warning for conditions that are meeting or approaching national in-flight advisory criteria (for example, AIRMETs, SIGMETs, or Convective SIGMETs) and are impacting the respective airspace. These short-term warnings are typically valid for 2 hours.

> Direct principal operations inspectors (POIs) to ensure that all 14 Code of Federal Regulations (CFR) Part 121 air carriers require their dispatchers to provide all pertinent information, including airman's meteorological information (AIRMETs) and Center Weather Advisories (CWAs), to flightcrews for preflight and in-flight planning purposes.

On April 24, 1997, the FAA stated that it issued Flight Standards Information Bulletin for Air Transportation 97-03 on March 17, 1997, which directed POIs to ensure that air carriers require dispatchers to provide pertinent information, including AIRMETs and CWAs, when appropriate, for preflight and in-flight planning purposes. The FAA also stated that the information in the bulletin would be incorporated into FAA Order 8400.10, "Air Transportation Operations Inspector's Handbook."[113] On August 20, 1997, the NTSB stated that the flight standards information bulletin addressed the intent of Safety Recommendation A-96-48 and classified it "Closed—Acceptable Action." However, this accident demonstrates that, even though the FAA took actions to address this safety issue, weather documents are still missing pertinent information, including AIRMETs.

In addition, the NTSB's review of the weather document for the accident flight revealed that some of the information was outdated. For example, the weather document included three CWAs, but they were not valid at the time of the accident flight.[114] Also, the wind and temperature aloft forecast for BUF, which was issued about 1300 and was valid between 1200 and 1600, had expired before the accident flight. This outdated information should not have been part of the weather document but was included in it because of programming limitations of Colgan's weather contractor subsystem.

Problems with weather documents have also been found at other Part 121 air carriers. For example, on April 12, 2007, Pinnacle Airlines flight 4712, a Bombardier/Canadair Regional Jet CL600-2B19, N8905F, departed the end of the runway while landing at Cherry Capital Airport, Traverse City, Michigan.[115] None of the 3 crewmembers and 49 passengers was injured; the airplane was substantially damaged. The accident flight's weather document, which was prepared by the Pinnacle Airlines dispatcher, did not include any National Weather Service (NWS) in-flight weather advisories. However, NWS AIRMETs for icing, turbulence, and instrument flight rules conditions were valid for the area at the time of the accident.

Also, on December 25, 2007, Alaska Airlines flight 464, a McDonnell Douglas DC-9-83, N943AS, encountered severe turbulence during the descent for landing at Ontario International

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[113] FAA Order 8400.10 has been superseded by FAA Order 8900.1.

[114] Two CWAs for low-level windshear, issued by the New York Air Route Traffic Control Center, had expired at 1320. A CWA for scattered thunderstorms, issued by the Cleveland Center, expired about 1630.

[115] For more information, see *Runway Overrun During Landing, Pinnacle Airlines, Inc., Flight 4712, Bombardier/Canadair Regional Jet CL600-2B19, N8905F, Traverse City, Michigan, April 12, 2007*, Aircraft Accident Report NTSB/AAR-08/02 (Washington, DC: NTSB, 2008).

Airport, Ontario, California.[116] Two flight attendants sustained serious injuries during the turbulence encounter, and the third flight attendant, the two flight crewmembers, and the 109 passengers were not injured. During its investigation of this accident, the NTSB determined that two NWS Significant Meteorological Information (SIGMET) advisories were not included in the weather document for the flight. The SIGMETs were issued before the flight's departure as a result of occasional severe turbulence for the Ontario area. The NTSB determined the probable cause of this accident was the lack of turbulence forecast information available to the flight crew, which resulted in the flight attendants not being seated when the flight encountered the severe turbulence. Contributing factors to the accident included the failure of the company that provided the flight's weather briefing information to forecast severe turbulence and the failure of the airline dispatcher to provide the SIGMETs to the flight crew.[117]

Flight crews need to be provided with an operationally useful weather document containing all relevant weather information, including AIRMETs and SIGMETs, for each flight so that they can make sound safety-of-flight decisions based on that information. Such documents must contain up-to-date information so that flight crews do not have to sort through outdated or unrelated information for their flight. The NTSB concludes that weather documents missing key weather products or containing products that are no longer valid prevent flight crewmembers from having relevant, readily available weather-related safety information for preflight and in-flight decision-making. Therefore, the NTSB recommends that the FAA require Part 121, 135, and 91K operators to revise the methodology for programming their adverse weather phenomena reporting and forecasting subsystems so that the subsystem-generated weather document for each flight contains all pertinent weather information, including AIRMET, SIGMET, and other NWS in-flight weather advisories, and omits weather information that is no longer valid. The NTSB further recommends that the FAA require POIs of Part 121, 135, and 91K operators to periodically review the weather documents generated for their carriers to verify that those documents are consistent with the information requested in Safety Recommendation A-10-32.

Icing Terminology

Chapter 7 of the AIM, Safety of Flight, section 7-1-21, describes the effects of ice on an aircraft and provides terminology for pilots to use when describing icing conditions to ATC. However, during its investigation of this accident, the NTSB found that the definitions for reportable icing intensities in the July 2008 version of the AIM had not been updated to reflect the definitions published in December 2007 in AC 91-74A, "Pilot Guide: Flight in Icing Conditions." The table shows the differences in terminology between AIM section 7-1-21(b) and AC 91-74A.

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[116] Additional information about this accident, NTSB case number SEA08LA050, is available on the NTSB's website.

[117] The NTSB discussed these weather-related issues with Alaska Airlines, which added NWS products to the weather subsystem used to generate its weather documents.

Table. Icing Definitions

Icing intensity	***Aeronautical Information Manual* definition**	**Advisory Circular 91-74A definition**
Trace	Ice becomes perceptible. Rate of accumulation is slightly greater than sublimation. Deicing/anti-icing equipment is not utilized unless encountered for an extended period of time (over 1 hour).	Ice becomes noticeable. The rate of accumulation is slightly greater than the rate of sublimation. A representative accretion rate for reference purposes is less than 1/4 inch (6 mm) per hour on the outer wing. The pilot should consider exiting the icing conditions before they become worse. Pilots should be aware that any ice, even in trace amounts, could be potentially hazardous.
Light	The rate of accumulation may create a problem if flight is prolonged in this environment (over 1 hour). Occasional use of deicing/anti-icing equipment removes/prevents accumulation. It does not present a problem if the deicing/anti-icing equipment is used.	The rate of ice accumulation requires occasional cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1/4 inch to 1 inch (0.6 to 2.5 cm) per hour on the outer wing. The pilot should consider exiting the condition.
Moderate	The rate of accumulation is such that even short encounters become potentially hazardous and use of deicing/anti-icing equipment or flight diversion is necessary.	The rate of ice accumulation requires frequent cycling of manual deicing systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is 1 to 3 inches (2.5 to 7.5 cm) per hour on the outer wing. The pilot should consider exiting the condition as soon as possible.
Heavy	None.	The rate of ice accumulation requires maximum use of the ice protection systems to minimize ice accretions on the airframe. A representative accretion rate for reference purposes is more than 3 inches (7.5 cm) per hour on the outer wing. Consider immediate exit from the conditions.
Severe	The rate of accumulation is such that deicing/anti-icing equipment fails to reduce or control the hazard. Immediate flight diversion is necessary.	The rate of ice accumulation is such that ice protection systems fail to remove the accumulation of ice, and ice accumulates in locations not normally prone to icing, such as areas aft of protected surfaces and any other areas identified by the manufacturer. Immediate exit from the condition is necessary.

Note: AC 91-74A also states that deicing or anti-icing systems are expected to be activated and operated continuously in the automatic mode, if available, at the first sign of ice accumulation or as directed in the AFM and that occasional and frequent cycling refers to manually activated systems. The AC further states that accretion rates can be measured by an icing rate meter.

As shown in the table, three main differences exist between the icing terminology in the AIM and AC 91-74A. First, the AC provides an accretion rate for each icing definition, which can help pilots evaluate and accurately describe the icing conditions. Second, the AC contains a fifth icing category—heavy—to explain the environment that occurs between moderate and severe icing, providing additional icing information for pilots to consider. Last, the AC includes more detailed guidance than the AIM for pilot actions in icing conditions, providing pilots with further information for addressing specific icing situations.

The light-to-moderate icing terminology used in the two PIREPs that were included in the weather document for the accident flight had likely portrayed accurate conditions at the time of the flight. Nevertheless, the NTSB is concerned that pilots transmitting airframe icing PIREPs may not be using the most updated definitions in determining and reporting the severity of icing. Although the AC is advisory only, it is important that the icing definitions and accretion rates in the AC be incorporated into the AIM because that publication is the FAA's official guide for basic flight information and ATC procedures. The NTSB concludes that detailed icing definitions that include accretion rates and recommended pilot actions would help pilots more accurately determine the icing conditions to report in airframe icing PIREPs and more effectively respond to those conditions. Therefore, the NTSB recommends that the FAA update the definitions for reportable icing intensities in the AIM so that the definitions are consistent with the more detailed intensities defined in AC 91-74A.

Therefore, the National Transportation Safety Board recommends that the Federal Aviation Administration:

> Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to review their standard operating procedures to verify that they are consistent with the flight crew monitoring techniques described in Advisory Circular (AC) 120-71A, "Standard Operating Procedures for Flight Deck Crewmembers"; if the procedures are found not to be consistent, revise the procedures according to the AC guidance to promote effective monitoring. (A-10-10)

> Require that airspeed indicator display systems on all aircraft certified under 14 *Code of Federal Regulations* Part 25 and equipped with electronic flight instrument systems depict a yellow/amber cautionary band above the low-speed cue or airspeed indicator digits that change from white to yellow/amber as the airspeed approaches the low-speed cue, consistent with Advisory Circular 25-11A, "Electronic Flight Displays." (A-10-11)

> For all airplanes engaged in commercial operations under 14 *Code of Federal Regulations* Parts 121, 135, and 91K, require the installation of low-airspeed alert systems that provide pilots with redundant aural and visual warnings of an impending hazardous low-speed condition. (A-10-12) (Supersedes Safety Recommendations A-03-53 and -54 and is classified "Open—Unacceptable Response)

> Issue an advisory circular with guidance on leadership training for upgrading captains at 14 *Code of Federal Regulations* Part 121, 135, and 91K operators, including methods and techniques for effective leadership; professional standards of conduct; strategies for briefing and debriefing; reinforcement and correction skills; and other knowledge, skills, and abilities that are critical for air carrier operations. (A-10-13)

> Require all 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to provide a specific course on leadership training to their upgrading captains that is consistent with the advisory circular requested in Safety Recommendation A-10-13. (A-10-14)

Develop, and distribute to all pilots, multimedia guidance materials on professionalism in aircraft operations that contain standards of performance for professionalism; best practices for sterile cockpit adherence; techniques for assessing and correcting pilot deviations; examples and scenarios; and a detailed review of accidents involving breakdowns in sterile cockpit and other procedures, including this accident. Obtain the input of operators and air carrier and general aviation pilot groups in the development and distribution of these guidance materials. (A-10-15) (Supersedes Safety Recommendation A-07-8)

Require all 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to address fatigue risks associated with commuting, including identifying pilots who commute, establishing policy and guidance to mitigate fatigue risks for commuting pilots, using scheduling practices to minimize opportunities for fatigue in commuting pilots, and developing or identifying rest facilities for commuting pilots. (A-10-16)

Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to document and retain electronic and/or paper records of pilot training and checking events in sufficient detail so that the carrier and its principal operations inspector can fully assess a pilot’s entire training performance. (A-10-17)

Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to include the training records requested in Safety Recommendation A-10-17 as part of the remedial training program requested in Safety Recommendation A-05-14. (A-10-18)

Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to provide the training records requested in Safety Recommendation A-10-17 to hiring employers to fulfill their requirement under the Pilot Records Improvement Act. (A-10-19)

Develop a process for verifying, validating, auditing, and amending pilot training records at 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to guarantee the accuracy and completeness of the records. (A-10-20)

Direct 14 *Code of Federal Regulations* Part 121, 135, and 91K operators of airplanes equipped with a reference speeds switch or similar device to (1) develop procedures to establish that, during approach and landing, airspeed reference bugs are always matched to the position of the switch and (2) implement specific training to ensure that pilots demonstrate proficiency in this area. (A-10-21)

Require 14 *Code of Federal Regulations* (CFR) Part 121, 135, and 91K operators and 14 CFR Part 142 training centers to develop and conduct training that incorporates stalls that are fully developed; are unexpected; involve autopilot disengagement; and include airplane-specific features, such as a reference speeds switch. (A-10-22)

Require all 14 *Code of Federal Regulations* Part 121, 135, and 91K operators of stick pusher-equipped aircraft to provide their pilots with pusher familiarization simulator training. (A-10-23) (Supersedes Safety Recommendation A-07-4)

Define and codify minimum simulator model fidelity requirements to support an expanded set of stall recovery training requirements, including recovery from stalls that are fully developed. These simulator fidelity requirements should address areas such as required angle-of-attack and sideslip angle ranges, motion cueing, proof-of-match with post-stall flight test data, and warnings to indicate when the simulator flight envelope has been exceeded. (A-10-24)

Identify which airplanes operated under 14 *Code of Federal Regulations* Part 121, 135, and 91K are susceptible to tailplane stalls and then (1) require operators of those airplanes to provide an appropriate airplane-specific tailplane stall recovery procedure in their training manuals and company procedures and (2) direct operators of those airplanes that are not susceptible to tailplane stalls to ensure that training and company guidance for the airplanes explicitly states this lack of susceptibility and contains no references to tailplane stall recovery procedures. (A-10-25)

Develop more stringent standards for surveillance of 14 *Code of Federal Regulations* (CFR) Part 121 135, and 91K operators that are experiencing rapid growth, increased complexity of operations, accidents and/or incidents, or other changes that warrant increased oversight, including the following: (1) verify that inspector staffing is adequate to accomplish the enhanced surveillance that is promulgated by the new standards, (2) increase staffing for those certificates with insufficient staffing levels, and (3) augment the inspector staff with available and airplane-type-qualified inspectors from all Federal Aviation Administration regions and 14 CFR Part 142 training centers to provide quality assurance over the operators' aircrew program designee workforce. (A-10-26)

Require all 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to (1) develop and implement flight operational quality assurance programs that collect objective flight data, (2) analyze these data and implement corrective actions to identified systems safety issues, and (3) share the deidentified aggregate data generated through these analyses with other interested parties in the aviation industry through appropriate means. (A-10-27)

Seek specific statutory and/or regulatory authority to protect data that operators share with the Federal Aviation Administration as part of any flight operational quality assurance program. (A-10-28)

> Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to (1) routinely download and analyze all available sources of safety information, as part of their flight operational quality assurance program, to identify deviations from established norms and procedures; (2) provide appropriate protections to ensure the confidentiality of the deidentified aggregate data; and (3) ensure that this information is used for safety-related and not punitive purposes. (A-10-29)

> Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to incorporate explicit guidance to pilots, including checklist reminders as appropriate, prohibiting the use of personal portable electronic devices on the flight deck. (A-10-30)

> Implement a process to document that all 14 *Code of Federal Regulations* Part 121, 135, and 91K operators have taken appropriate action in response to safety-critical information transmitted through the safety alert for operators process or another method. (A-10-31)

> Require 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to revise the methodology for programming their adverse weather phenomena reporting and forecasting subsystems so that the subsystem-generated weather document for each flight contains all pertinent weather information, including Airmen's Meteorological Information, Significant Meteorological Information, and other National Weather Service in-flight weather advisories, and omits weather information that is no longer valid. (A-10-32)

> Require principal operations inspectors of 14 *Code of Federal Regulations* Part 121, 135, and 91K operators to periodically review the weather documents generated for their carriers to verify that those documents are consistent with the information requested in Safety Recommendation A-10-32. (A-10-33)

> Update the definitions for reportable icing intensities in the *Aeronautical Information Manual* so that the definitions are consistent with the more detailed intensities defined in Advisory Circular 91-74A, "Pilot Guide: Flight in Icing Conditions." (A-10-34)

Also, the National Transportation Safety Board reiterates the following recommendations to the Federal Aviation Administration:

> Require all Part 121 and 135 air carriers to obtain any notices of disapproval for flight checks for certificates and ratings for all pilot applicants and evaluate this information before making a hiring decision. (A-05-1)

> Require all 14 *Code of Federal Regulations* Part 121 air carrier operators to establish training programs for flight crewmembers who have demonstrated performance deficiencies or experienced failures in the training environment that would require a review of their whole performance history at the company and

> administer additional oversight and training to ensure that performance deficiencies are addressed and corrected. (A-05-14)
>
> Require that all pilot training programs be modified to contain modules that teach and emphasize monitoring skills and workload management and include opportunities to practice and demonstrate proficiency in these areas. (A-07-13)

In addition, the National Transportation Safety Board reclassifies the following recommendations to the Federal Aviation Administration:

> Safety Recommendation A-07-13 is reclassified "Open—Unacceptable Response."
>
> Safety Recommendations A-03-53 and -54 are reclassified "Closed—Unacceptable Action/Superseded." The recommendation is superseded by Safety Recommendation A-10-12.
>
> Safety Recommendation A-07-8 is reclassified "Closed—Unacceptable Action/Superseded" The recommendation is superseded by Safety Recommendation A-10-15.
>
> Safety Recommendation A-05-1 is reclassified "Open—Unacceptable Response."
>
> Safety Recommendation A-07-4 is reclassified "Closed—Unacceptable Action/Superseded." The recommendation is superseded by Safety Recommendation A-10-23.

In response to the recommendations in this letter, please refer to Safety Recommendations A-10-10 through -34 and Safety Recommendations A-05-1, A-05-14, and A-07-13. If you would like to submit your response electronically rather than in hard copy, you may send it to the following e-mail address: correspondence@ntsb.gov. If your response includes attachments that exceed 5 megabytes, please e-mail us asking for instructions on how to use our Tumbleweed secure mailbox procedures. To avoid confusion, please use only one method of submission (that is, do not submit both an electronic copy and a hard copy of the same response letter).

Chairman HERSMAN, Vice Chairman HART, and Member SUMWALT concurred with these recommendations. All Board Members filed concurring statements, which are attached to the aviation accident report for this accident.

[Original Signed]

By: Deborah A.P. Hersman
Chairman

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
A-10-013	1	AAR-19-02	3/28/2019	Departure from Controlled Flight Trans-Pacific Air Charter, LLC, Learjet 35A, N452DA, Teterboro, New Jersey, May 15, 2017	Teterboro	New Jersey	5/15/2017

Safety Recommendation Reiteration List

SR Number	Reiteration Number	Report Number	Report Date	Accident Description	Accident City	Accident State	Accident Date
A-10-014	1	AAR-19-02	3/28/2019	Departure from Controlled Flight Trans-Pacific Air Charter, LLC, Learjet 35A, N452DA, Teterboro, New Jersey, May 15, 2017	Teterboro	New Jersey	5/15/2017