Submission of the
Air Line Pilots Association, International
to the
National Transportation Safety Board
Regarding the Accident Involving

Colgan 3407

DHC-8-Q400

DCA09MA027

Clarence Center, NY

February 12, 2009

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Acronyms/ Definitions

ACARS	Aircraft Communications and Reporting System
AFM	Aircraft Flight Manual
ALPA	Air Line Pilots Association
AOA	Angle of Attack
AOM	Aircraft Operating Manual
APM	Aircraft Program Manager (FAA)
ASAP	Aviation Safety Action Program
ATIS	Automatic Terminal Information Service
ATP	Airline Transport Pilot
CFM	Company Flight Manual
CFR	Code of Federal Regulations
CRM	Crew Resource Management
CVR	Cockpit Voice Recorder
EADI	Electronic Attitude Director Indicator
ED	Engine Display
EST	Eastern Standard Time
FAA	Federal Aviation Administration
FAR	Federal Aviation Regulations
FDR	Flight Data Recorder
FOPPM	Flight Operations Policy & Procedures Manual
FOQA	Flight Operations Quality Assurance
GS	Glideslope
ICAO	International Civil Aviation Organization

IEP	Internal Evaluation Program
ILS	Instrument Landing System
IMC	Instrument Meteorological Conditions
IOE	Initial Operating Experience
KIAS	Knots- Indicated Airspeed
LOSA	Line Operations Safety Audit
MEL	Minimum Equipment List
MSL	Mean Sea Level
NASA	National Aeronautics and Space Administration
NM	Nautical Mile
Q400	Dash 8-Q400 (DHC-8-400)
QRH	Quick Reference Handbook
PC	Proficiency Check
PF	Pilot Flying
PFD	Primary Flight Display
PLA	Power Lever Angle
PLI	Pitch Limit Indicator
PM	Pilot Monitoring
POI	Principle Operations Inspector (FAA)
PTS	Practical Test Standards
SAFO	Safety Alert For Operators
SMS	Safety Management Systems
SOP	Standard Operating Procedure
SPS	Stall Protection System
TOLD	Take Off and Landing Data

V_1	Take-off Decision Speed
V_2	Take-off Safety Speed
V_{app}	Approach Speed
V_{cl}	Climb Speed
V_{fri}	Initial Flap Retraction Speed
V_{ga}	Go-Around Speed
V_r	Rotation Speed
V_{ref}	Approach speed at 50’ above the runway

Executive Summary

On February 12, 2009, at approximately 2217 Eastern Standard Time (EST) Colgan flight 3407, a Bombardier DHC-8-Q400 crashed during an instrument approach in night instrument meteorological conditions (IMC) to Runway 23 at Buffalo-Niagara International Airport (BUF). The flight was a Code of Federal Regulations (CFR) Part 121 scheduled passenger flight being operated by Colgan Air, Inc. as a Continental Connection flight from Newark Liberty International Airport (EWR) to Buffalo. The accident site was located approximately 5 nautical miles (nm) northeast of the airport, in Clarence Center, NY. The 2 flight crew, 2 cabin crew, and 45 passengers were fatally injured and the aircraft was substantially damaged by impact forces and a post-crash fire. There was also one ground fatality.

The purpose of this analysis is to identify the specific chain of events ("findings") that led to the accident and from that make recommendations to avoid reoccurrence of similar events. This was a classic stall/spin accident, with multiple contributing human, materiel, and situational factors. Analysis of the flight crew's performance reveals some errors, but neither "pilot error" nor any one of the many other factors was "the cause" of this accident. Our analysis identifies key failures prior to the accident in the regulatory, organizational, and supervisory structure. These created latent conditions conducive to failure of the system. That is, failures that in and of themselves were not hazards, but which in the presence of other factors contributed to the accident sequence. These failures, if left unchanged, will continue to be a threat to cause accidents and incidents in the future. Without proper mitigations, these latent conditions exacerbated active perceptual and skill based errors by the accident crew.

Reasonable and rational human beings conducting normal operations can be placed in adverse situations resulting from the confluence of these latent factors, even when acting in a professional and responsible manner. Frequently the difference between a good and bad outcome of an active error is that many negative influences that existed months prior manifested themselves together just prior to the accident. If this collection of latent conditions and active failures is not quickly identified and controlled, an accident can ensue.

When considering failures of high reliability organizations, the complex, interactive nature of the organization must be examined. ALPA supports the ICAO model that accident analysis is not intended to assign blame or liability, or excuse human error (International Civil Aviation Organization, 2001). By identifying as many contributing factors as possible, we hope to improve performance of high reliability organizations within the system and prevent future accidents.

ALPA's analysis shows that although the Captain and First Officer were at the controls the night of February 12, 2009, there were numerous latent conditions which were factors in this accident. The crew's actions, along with all other relevant factors, are examined and our analysis identifies a number of possible reasons for the crew's actions.

Based on the analysis from the aircraft performance work, icing, although present, was within the operating limits of the aircraft and the anti-icing systems appear to have been operating correctly. The precipitating event of the upset was the stick shaker and autopilot disconnect followed by the increase in pitch and the subsequent flap retraction which caused the aircraft to enter a stall from which the crew did not recover.

The Captain's apparent aft control column movement can be attributed to either a reaction to the training he had received from Colgan on tailplane stalls, his concern about the proximity to the ground, and/ or he was experiencing a somatogravic illusion (i.e. "spatial disorientation"). During the remainder of the upset the Captain's control inputs were consistent with stall training provided by Colgan, which was to level the wings and keep the aircraft's pitch on the PFD level on the horizon. The Captain did this until the aircraft was too deep into the stall to maintain a level pitch attitude. The aft control column movements by the Captain towards the end of the event may have been the result of EGPWS activation. Although the aural warning was inhibited due to the stick shaker activation, the "Pull-Up" light would have been illuminated in his forward field-of-view. The First Officer's uncommanded retraction of the flaps can be attributed to either her reaction to training she had received from Colgan on tailplane stalls or that during her wing stall training, as the non-flying pilot, the only action she was consistently required to performed was to raise the flaps and retract the landing gear. This is clearly supported by her next action after raising the flaps, which was to ask about bringing the gear up. Since we do not have any verbal cues from the crew, determining which of these behaviors is correct is not possible.

The Q400 design did not include a minimum maneuvering speed/ low speed alert, which would have provided this accident crew an additional visual/ aural cue of the deceleration of the aircraft. The low speed cue on the Q400 provides only a visual display. Once the airspeed is at that cue the autopilot will disconnect and the stick shaker will activate, potentially leading to a surprised crew needing to handle an emergency situation. In the case of this accident, the crew was in night IMC and based on the deceleration of the aircraft, it is possible that one or both pilots were suffering from the effects of a somatogravic illusion.

The training provided by Colgan to this crew was deficient. The Colgan training was incomplete, incorrect, and did not provide this crew with the tools they needed to appropriately manage this event. Effective CRM training would have provided pilots information on how to communicate their thoughts and actions, as well as relevant scenario-based training to give these pilots examples of how to communicate during emergency/ abnormal events. Colgan's use of training on tailplane stalls (a NASA video) as "icing training" was incomplete. It did not provide these pilots with the differences which would be experienced in the Q400 versus the Twin Otter used in the NASA video. There was no discussion of the fact that a stick shaker is *only* indicative of a wing stall, not a tailplane stall. The stall training failed to emphasize the true aerodynamic wing stall recovery procedures; rather, Colgan procedures focused on pilots maintaining altitude and heading. The crew's actions during the accident sequence were consistent with such an attempt. Colgan did not provide crews with stick pusher training, which would have provided this crew additional information that might have allowed them to successfully recover from this upset. However, pusher training, even if provided, has limitations due to the inadequate fidelity of simulators in certain realms of flight. Simulator fidelity in these expanded flight regimes must be improved and be acceptable to perform stick pusher training.

The manuals provided by Colgan, which the crew was trained on, were incomplete. In an effort to get the Q400 quickly approved for Part 121 operations, Colgan avoided authoring an all encompassing Company Flight Manual (CFM) and provided crews with an interim CFM that contained only a fraction of the information that this crew needed to operate this aircraft. The CFM contained only limitations, not operational procedures for operating in icing conditions. In particular, “operations in icing conditions” was edited to one paragraph from the four pages in the AFM.

During the investigation, the FAA POI described Colgan as a reactive versus proactive organization. The organizational culture at Colgan was primarily punitive. Examples were memos that prohibited rest/sleep/nap in lieu of any enlightened fatigue/rest provisions, a monetarily punitive sick leave policy[1], and threats of discipline, up to termination, for documenting returns to the gate for problems which were later to be determined to be inadvertent. The primary reporting process (ASAP) and other reporting systems were not effective and collected minimal operational data from crews, either due to lack of understanding or a perceived punitive nature of the program. Colgan had no FOQA program and the pseudo-LOSA program was described by Colgan management personnel as not being administered appropriately.

Individually, any of these factors, while important to address, would not likely have led to an accident. However, the combination of deficiencies in training, corporate culture, darkness, IMC, available guidance, and skill-based errors led to a situation in which the crew had insufficient resources to effect a successful recovery.

[1] Colgan Air, Inc. Public Hearing Day 2, Pages 333-335

1.0 Factual Information

1.1 History of Flight

The accident crew reported for duty at 1330 EST[2] for a Rochester, NY (ROC) roundtrip which was cancelled. There were high winds in the Newark, NJ area and Continental Airlines had called the Colgan Regional Chief Pilot to cancel multiple Continental Connection flights operated by Colgan.[3] Flight 3407 was scheduled to depart at 1910 EST with a scheduled arrival time in Buffalo at 2048 EST. The flight left the gate thirty-five minutes late at 1945 EST and contacted Flow Control at 2012 EST. Newark Ground gave Flight 3407 taxi clearance at 2030 EST, was instructed to monitor Newark Tower at 2036 EST, and advised them they were number sixteen for departure. At 2118 EST, Newark Tower cleared Flight 3407 for take-off from Runway 22R at taxiway Whiskey, the Captain was the Pilot Flying (PF).

The flight proceeded normally at 16,000' Mean Sea Level (MSL) along the route direct the COATE intersection Victor Airway 126 the Lake Henry VOR (LHY) direct Elmira (ULW) direct the BENEE intersection Victor Airway 164 the Buffalo VOR (BUF). As the flight was approaching Buffalo, the crew requested a descent to 12,000' MSL, Cleveland Center cleared Flight 3407 to cross the BENEE intersection at 11,000' MSL.

As the flight was approaching the BENEE intersection, Cleveland Center instructed Flight 3407 to contact Buffalo Approach. Buffalo Approach advised Flight 3407 to plan an Instrument Landing System (ILS) approach to Runway 23. The weather report from the Buffalo Automatic Terminal Information Service (ATIS) Information 'Romeo' was reporting wind 250 at 15 knots gusting to 23 knots, visibility 3 statute miles in light snow and mist, few clouds at 1,100, ceiling 2,100 overcast, temperature 1°C, dew point -1°C, altimeter 29.78 inches of mercury. The flight was descended to 2300' MSL and vectored to intercept the final approach course. Buffalo Approach cleared Flight 3407 for the ILS Approach to Runway 23 at 2215:14 EST and almost a minute later at 2216:07 EST instructed Flight 3407 to contact Buffalo Tower.

During the approach sequence the crew configured the aircraft to Flaps 5 and as the aircraft began to intercept the localizer the crew lowered the gear. Two seconds later the Pilot Flying called for Flaps 15[4] and the Before Landing checklist. Almost 4 seconds later the stick shaker was audible on the Cockpit Voice Recorder (CVR) and it continues for approximately 6.7 seconds. The crew advanced the Power Levers to 75% torque, the First Officer selected flaps zero. The First Officer then told the Captain that she retracted the flaps and asked if the gear should also be retracted, to which he replied "gear up", 7 seconds later the CVR ceased recording.

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[2] The Captain began his duty day around noon by performing administrative tasks for the company.
[3] Group Chairman's Factual- Operations Group, Page 2
[4] Although the Captain requested the Flaps be set to 15, the Flight Data Recorder (FDR) shows that the flap handle was only extended to the Flaps 10 detent.

2.0 Analysis

2.1 Aircraft Performance

The performance of the Q400 involved in this accident was evaluated both by examining the Flight Data Recorder (FDR) information and utilizing an engineering simulation. The areas of interest related to the aircraft performance involved evaluating the degradation due to the effects of icing and the impact of the control inputs. There was specific attention given to the onset of the upset and the initial pitch-up.

Prior to the upset, the aircraft was level at 2300' MSL at 170-175 knots with the autopilot engaged. The flaps were selected from 0° to 5° and as the flaps transitioned the aircraft climbed approximately 50'. As the autopilot descended the aircraft back to 2300', the airspeed increased to 180 knots (the aircraft is not equipped with autothrottles). The aircraft then began a left turn to heading 260. Forty-two seconds later, at 22:15:59.9, the power levers were retarded to 42° power lever angle, at an airspeed of 185 knots. At 22:16:05.9, the landing gear was selected down and then at 22:16:09.9, the condition levers were set to MAX. At 22:16:24.9, the Ice Detected message was annunciated on the bottom on the Engine Display (ED). One second later, flaps were selected to 10° and after an additional second the autopilot disengaged. On the DFDR, the autopilot disengaging did not exactly coincide with the stick shaker activation, but this was likely due to the sampling rate of the stick shaker parameter. Therefore the autopilot disengaging likely best indicates the onset of the stick shaker. A second after the autopilot disengaged, aft control column movement is applied and the power levers were advanced to 70° power lever angle. The pitch-up moment experienced by the aircraft can most likely be attributed to the combination of the aft control column movement, the flaps transitioning from 5° to 10°, and the increase in engine torque. This pitch-up moment was accompanied by a roll to the left and once the aircraft reached 45° left wing down the aircraft then began to roll back to the right. At 22:16:33.9, as the aircraft passed through wings level, flaps are selected to 0° and the stick pusher fires. The retraction of the flaps created a pitch down moment, which was countered by control column input, which subsequently increased the angle of attack. The right roll continued to 105° and the aircraft then began to roll back to the left. Four seconds later, at 22:16:41.9, the stick pusher activated a second time. The aircraft rolled through wings level and continued its left roll to 35° and the aircraft then began to roll back to the right. At 22:16:45.9, the gear was selected up and the pitch was -5° with an angle of attack of +32°. The aircraft once again passed through level and continued its right roll to 100°. A half second prior to the end of the flight data recorder information, the aircraft had a pitch of -30°, an angle of attack of +35°, and 25° right wing down.

The effects of icing on the accident aircraft were evaluated using both an engineering simulation and kinematics parameter extraction.[5] Bombardier uses a 0.0 to 1.0 scale to evaluate the ice accumulation factor on the Q400, where 0.0 represents a clean aircraft and 1.0 represents an aircraft with the

[5] Kinematics parameter extraction method can be equated to a simulation dynamic trim calculation for each point in the data time history, where the aircraft motion data (i.e., linear and angular accelerations derived from load factor and attitude data, respectively) define the trim target- Aircraft Performance Simulation Study, Page 4

equivalent ice contamination demonstrated during FAR 25, Appendix C certification testing. The results of these simulations demonstrate that there was ice degradation on the Q400, but it was within the operating envelope of the aircraft. The best match of the results showed an ice accumulation factor of 0.1 to 0.2.

2.2 Bombardier DHC-8-400

2.2.1 Reference Speed Switch

Bombardier, with the introduction of the Q400 to the Dash 8 series, added a new element to the Stall Protection System (SPS) called the Reference Speeds switch, for use when operating in icing conditions. The Reference Speeds switch is designed to increase the stall margin provided by the Stall Protection System when selected to the INCR position. When this switch is in the INCR position the Stall Protection System uses a lower Angle Of Attack threshold for activation of the stick shaker, effectively providing stall warning at a higher speed under normal flight conditions. This is displayed to the crews by the low speed cue advancing up the airspeed tape on the Primary Flight Display by approximately 15-25 knots, depending on flap position. When the Reference Speeds switch is in the INCR position there is also a white “INCR REF SPEED” message posted on the ED.

Low Speed Cue

Solid and Open “Bugs”

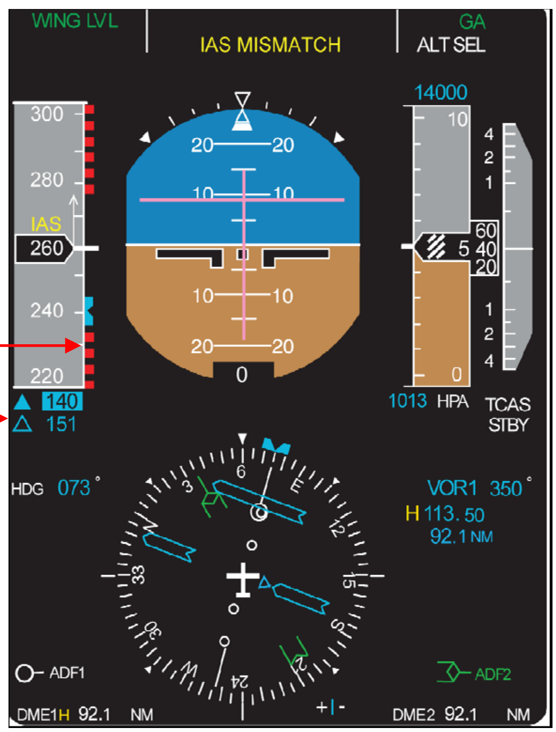


Figure 1- Q400 Primary Flight Display[6]

[6] Colgan Air, Inc Flight 3407 Public Hearing- Wally Warner and Harlan Simpkins Presentation (Low Speed Cue/ Solid and Open “Bugs” text added)

2.2.2 Crew Preselected "bugged" Speeds

Colgan procedure for the Q400 was to "bug"[7] five speeds for takeoff and two speeds for landing. The takeoff speeds bugged were V_1, V_r, V_2, V_{fri}, V_{cl}. The landing speeds bugged were V_{ref} and V_{ga}. These speeds were calculated to reflect real time factors such as weight, temperature, and landing runway. In addition to V_{ref} and V_{ga}, when the crew received landing data they would also be provided V_{fri} and V_{cl} even though the Q400 only allows for 2 bugs to be set for landing. Aerodata was the company responsible for sending the crews the proper takeoff and landing speeds via ACARS. In the event an ACARS link between Aerodata and the crew was not available, the crews had back-up procedures in place to obtain takeoff and landing data. These procedures included using takeoff and landing data found on the dispatch release and using the speed cards available in each aircraft. Additionally, charts located in the aircraft quick reference handbook (QRH) could also be used to determine landing speeds and required runway available for landing.

The guidance available to Colgan crews on setting bug speeds and the speeds to be flown during an approach were deficient in several areas. One area involved the use of keywords that had to be manually entered into ACARS in order to obtain speeds for use in icing conditions. In addition, conflicting and ambiguous information on proper use of speed adjustments in icing was noted among most Colgan pilots. Finally, the Colgan Q400 interim CFM did not address the use of a standardized approach speed to fly during the final approach to landing. This led to Colgan pilots having different understandings regarding what speed to fly on final approach. Some pilots flew it fast, while others would fly it slower.

To acquire the performance information from Aerodata, crews would select the desired runway and enter the current field conditions into the ACARS, then they would be able to manually enter specific keywords for additional data for icing conditions. The relevant keywords were "ICING" and "EICE", both of which had to be typed into the ACARS terminal manually. The only reference the pilots had at the time of the accident regarding the use of these keywords came from the Colgan Q400 interim CFM. The interim CFM defined the keywords "ICING" as used for icing conditions and "EICE" as used for enroute ice accumulation. Although the CFM gave a definition of the keywords, there was no guidance on when to use them. Several Colgan pilots interviewed were under the misconception that guidance for operating the Q400 in icing conditions could be found in the Q400 interim CFM, indicating their training had not adequately covered the subject. A review of the interim CFM revealed the only text published was limitations for operating in icing conditions and a definition of icing conditions. No actual icing systems operation was available.

In addition, prior to the accident, the flight simulators used by Colgan were not equipped with ACARS trainers. Therefore, Colgan crews would first learn how to operate the ACARS unit while going through initial operating experience (IOE). Thus, the first chance Colgan pilots were afforded to utilize the Aerodata computations and keywords was in revenue service in icing conditions. When crews entered the keywords "ICING" or "EICE," the Aerodata-supplied landing numbers V_{ref}, V_{ga}, V_{fri} and V_{cl} would be

[7] To visually depict critical speeds during flight, especially during take-off and landing, using symbology (solid and open triangles), called "bugs"(**Figure 1**)

generated with a 15 – 25 knots increase adjustment for flight in icing conditions or actual ice contamination on the aircraft. During the investigation, it was discovered that although the keywords were required to be manually typed into the ACARS, the system contained no "error traps" for misspellings, and in fact, ignored misspelled keywords with no indication given to the crew. Previously, Colgan taught that if a crew sent a request for landing data and misspelled a keyword such as "ICING" or "EICE", e.g. "ICNIG", the crew would receive an error message in the remarks section of the message sent back to the crew.[8] During the investigation it was determined that this was not the case. Thus, if the crew typed in the word "ICING" the correct speeds would be displayed, but if they typed the word incorrectly, e.g. "ICNIG" the system would display no error message and return erroneously low speeds intended for use with no ice present.

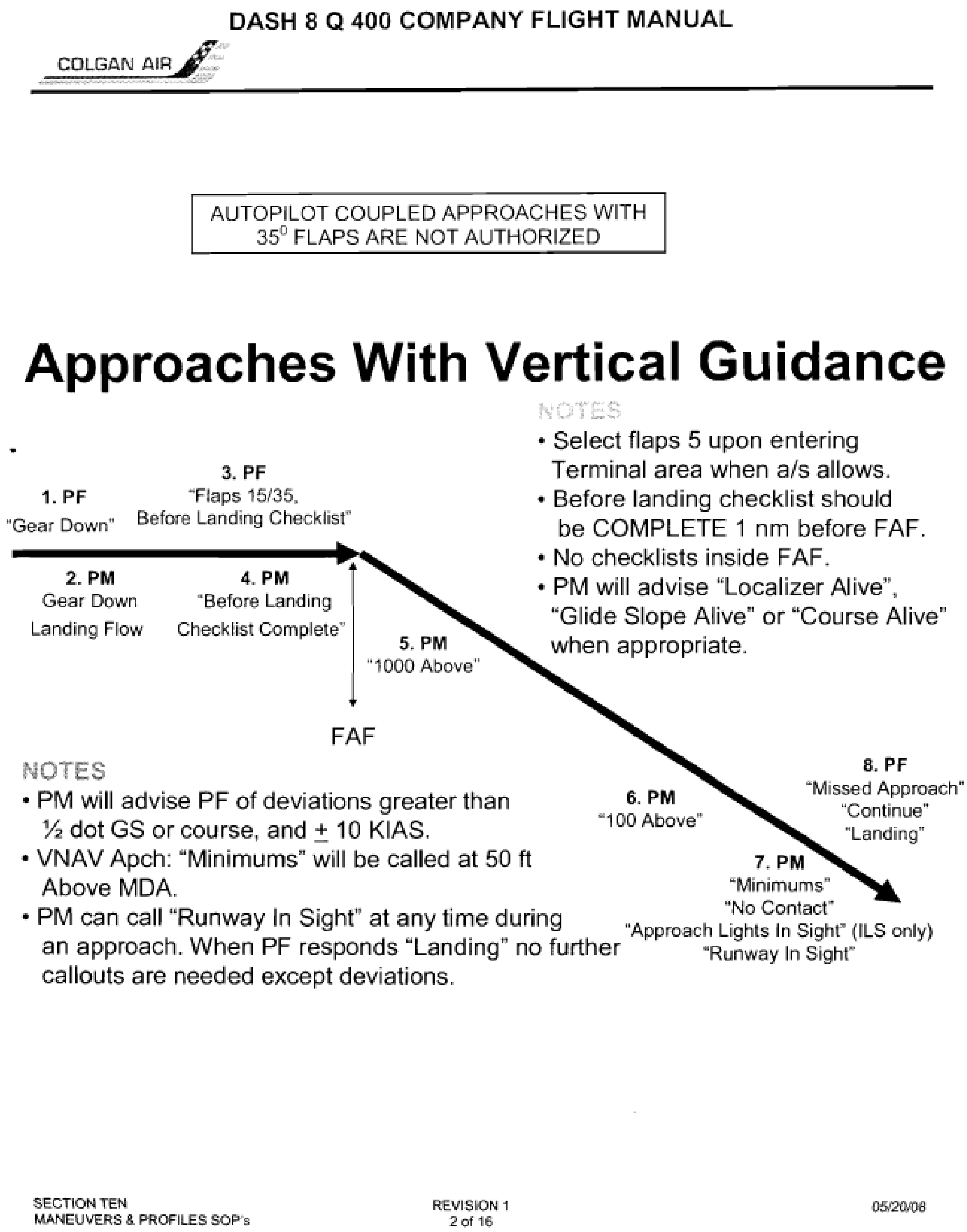
If higher "ice" speeds were set, the interim CFM did not state at what point (if ever) a crew could adjust to the lower "clean" landing speeds should the aircraft be free of ice contamination and out of icing conditions. Conversely, the manufacturer's aircraft flight manual, to which crews had no direct access outside the flight deck, did specify parameters for which crews were required to adjust or readjust speeds. This could lead to crews inappropriately adjusting speeds during the approach and landing phase of flight. Other Q400 operators have shown the use of these "icing" speeds can be done in a very standardized manner. Horizon Air stated in an interview they decided to set bugs in a way that would avoid confusion, especially because of the Reference Speeds switch. Horizon always sets their bugs the same way. They bug the solid bug at $V_{ref-icing}$ and the open bug at $V_{ref-clean}$ (**Figure 1**). There is no switching of speed bugs during the approach and landing phase of flight.[9]

Interviews with Colgan crews also indicated that the Colgan Q400 operation lacked a standardized approach speed schedule. This suggests that both the training and manuals for the Q400 were deficient. The FAA APM stated that the training called for flying final at V_{ref} plus 10 knots. However, V_{ref} plus 10 knots was not found in the Colgan FOPPM or CFM. One Colgan captain interviewed said it was his practice to fly the final approach at V_{ref} plus 20 knots.[10,11] Other pilots interviewed were not specific as to approach speed flown. A Colgan Q400 check airman stated he flew V_{ref} while on final approach and expected the pilot monitoring to make deviation callouts of plus or minus 5 knots.[12] When asked if that is Colgan policy, he replied "that is just personal technique."[13]

Although the aircraft QRH contained charts to determine approach speeds, Colgan procedures did not require crews to utilize these charts. An example of the incomplete guidance given to Colgan crews is the "approach with vertical guidance" profile (**Figure 2**). This chart is the only guidance provided and simply states "PM will advise PF of deviations greater than ½ dot GS or course, and ±10 KIAS," but does not specify to what speed ±10 KIAS is referenced. The Colgan Q400 landing profile also did not provide

[8] Operations Group Chairman's Factual Report – Addendum 3, Page 46
[9] Operations Group Chairman's Factual Report – Addendum 3, Attachment 4
[10] Group Chairman's Factual- Operations Group, Page 32
[11] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 20
[12] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 69
[13] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 69

guidance for speed corrections to V_{ref} for strong or gusty winds, contrary to common practice in the industry. This led to pilots applying their own procedures or using guidance provided for aircraft they had previously flown.


DASH 8 Q 400 COMPANY FLIGHT MANUAL

COLGAN AIR

AUTOPILOT COUPLED APPROACHES WITH 35^0 FLAPS ARE NOT AUTHORIZED

Approaches With Vertical Guidance

NOTES
- Select flaps 5 upon entering Terminal area when a/s allows.
- Before landing checklist should be COMPLETE 1 nm before FAF.
- No checklists inside FAF.
- PM will advise "Localizer Alive", "Glide Slope Alive" or "Course Alive" when appropriate.

NOTES
- PM will advise PF of deviations greater than ½ dot GS or course, and ± 10 KIAS.
- VNAV Apch: "Minimums" will be called at 50 ft Above MDA.
- PM can call "Runway In Sight" at any time during an approach. When PF responds "Landing" no further callouts are needed except deviations.

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Figure 2- Colgan Q400 CFM (Section 10 Page 2)

In addition to the landing speeds V_{ref} and V_{ga}, the crews were also supplied V_{fri} and V_{cl} speeds. Due to the design of the Q400, there is no method to bug these important numbers on the PFD during landing. These numbers would be required in the event of a missed approach, go around, or stall. Some operators, including Colgan, report writing V_{fri} and V_{cl} down on paper.[14] Although Colgan procedure at the time of the accident was to record V_{fri} and V_{cl} on a TOLD card, a review of the Colgan interim CFM does not mention or give guidance on TOLD card use. The interim CFM also does not give guidance for standardized placement of the TOLD card within the flight deck. Porter Airlines comments they train their pilots to use a method in which the last two digits in V_{fri} and V_{cl} are placed in the standby transponder for reference should they be needed.[15] ALPA believes that Bombardier should modify their software to allow these speeds to be bugged.

2.2.3 Aircraft Design Considerations

Aircraft design advances and modifications contribute significant improvements in aircraft handling and crew response during critical flight regimes. This represents a significant safety improvement in that under extreme conditions, the improved handling allows crews to concentrate more on evaluating abnormal situations and less on the mechanics of basic aircraft control. Control of this accident aircraft was lost during approach to stall recovery response and the subsequent inadvertent stall. The aircraft was intentionally being slowed and configured for landing. However, the airspeed was allowed to decelerate until the stick shaker activated. The regulations under which this aircraft was certified were frozen at the application of the original type certificate in 1995. During the time since, changes have been proposed to FAR Part 25 made affecting certification regulations that would have required speed protection or aural and visual alerting while under flight guidance or autopilot control. The design of the accident Q400, manufactured in 2008, does not fully reflect the latest technology or functionality that is available to aircraft today. While it cannot be said definitively that such design changes would have prevented the accident, analysis of the facts surrounding the accident suggest that design improvements could reduce the likelihood of similar circumstances deteriorating to the point of catastrophe.

2.2.3.1 Minimum Maneuvering Speed/ Low Speed Alert

On some aircraft a **Minimum Maneuvering Speed** is calculated and displayed on the airspeed band. This minimum maneuvering speed indication provides a pilot with a speed representing a safe margin above a critically low speed (e.g. stall) to allow for variations encountered while maneuvering the aircraft in the current configuration. On some airplanes, a **Low Speed Alert** with visual and aural annunciation is activated when the aircraft speed drops below this value. This provides a pilot with sufficient advance warning to observe and correct airspeed prior to stall warning and the need for a subsequent recovery maneuver. According to Bombardier, the reason a low speed warning was not included "was a design decision taken at the time of the initial development of the aircraft."[16]

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[14] Operations Group Chairman's Factual Report – Addendum 3, Attachment 4
[15] Operations Group Chairman's Factual Report – Addendum 3, Attachment 4
[16] Colgan Air, Inc. Flight 3407 Public Hearing Day 1, Page 135

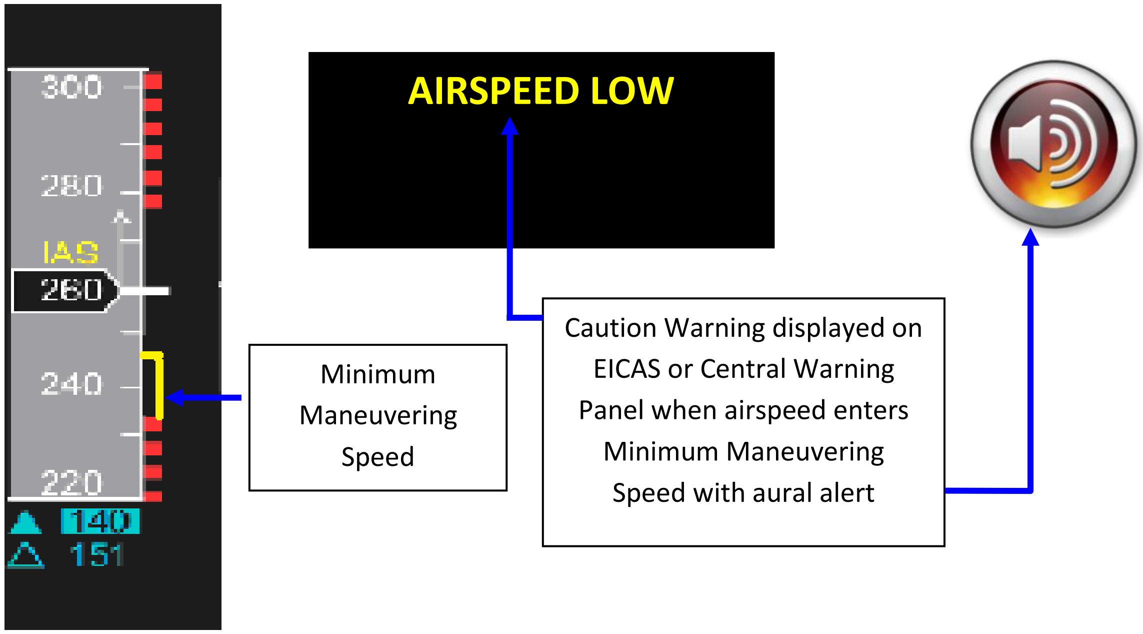

Figure 3- Minimum Maneuvering Speed and Message

2.2.3.2 Trim in Motion

Trim in motion annunciation is available on certain aircraft. It is a certification requirement for certain aircraft primarily based on detection of runaway trim. However, pilots also learn that it is an audible indication of large pitch force changes when the autopilot is engaged. This serves as a perceptual cue for large airspeed changes as well. Large unmonitored changes in aircraft controls state have been responsible for many aircraft accidents and incidents. New aircraft design philosophies favor “silent” cockpit conditions during normal operations. Most modern trim systems do not have audible motion indication. Audible trim in motion indication can serve as a useful indication of large changes in aircraft pitch and airspeed.

2.2.3.3 Counter-Rotating Propellers

Propeller powered aircraft have handling characteristics that can be far more demanding than turbojet powered aircraft. The rotation of propellers can generate roll and yaw forces, strongest during high powered, low airspeed flight. This can require significant control deflection of rudder and ailerons to counteract. Torque force created by the force of the engine and propeller rotation creates an opposite roll moment to the left. The most significant force is adverse yaw called p-(propeller) factor. Due to the angle of the aircraft’s longitudinal axis to the relative wind, the angle of attack of the downward traveling propeller blades is greater than those in upward travel. This result is an offset of the center of thrust for the propeller disc in the direction of rotation (clockwise). The result is an offset in the aircraft’s center of thrust to the right of the longitudinal axis and the subsequent left yawing motion. This requires the pilot to apply right rudder to counteract yaw force and right aileron to counteract roll force. Pilots will normally hold the wings level and apply rudder to maintain constant heading. Significant coordination of control forces is required by the pilot during low speed powered flight. Not properly balancing these forces will create an aerodynamic skidding condition which creates drag that reduces performance and can cause the aircraft to have a strong tendency to roll abruptly to one side if stalled. Left turning forces created by the propellers on the Q400 are normally held in balance primarily by trimming of rudder. Any significant change in airspeed, power or angle of attack requires subsequent change in rudder trim.[17] During climbing and descending level offs, large yaw changes accompany changes in thrust. This may be more pronounced at lower altitudes when maximum airspeed is restricted to 250 knots. This increases pilot workload and can serve as a distraction in some conditions.

Propellers geared to rotate in opposite directions can greatly reduce these forces. The torque and p-factor on one engine are countered by opposing forces on the other engine so offsetting flight control forces are not normally required during changes in flight regimes. Further, engines are usually installed so that downward blades are closer to the fuselage. This keeps the asymmetric forces created by p-factor closer to the aircraft longitudinal axis. This reduces adverse turning force during emergency single engine flight as well. **Counter rotating propellers** are available on other turboprop aircraft[18] and are commonly marketed for adding safety and stability.

2.2.3.4 Pitch Limit Indicator/ Angle of Attack Indicator

Aerodynamic wing stall occurs when the aircraft's wing exceeds the critical angle of attack. Angle of attack, α, is the angle between the wings chord line and the relative wind. As an aircraft slows down or turns more lift is required to maintain level flight, which requires an increase in angle-of-attack toward the critical angle-of-attack limit." As the critical angle of attack is reached, the airflow around the wing no longer remains stable. When this occurs, there is a dramatic loss of lift and increase in drag; the wing is then said to be in a "stalled" condition. In level flight this will occur at a certain airspeed. An increase in aircraft weight causes an increase in stall speed. Environmental factors can also affect wing stall. Ice contamination of the wing surface actually changes the shape of the airfoil and will cause an increase in stall speed. Manufacturers recommend approach or landing speeds by using a percentage over the stall speed for a given weight, thus affording a margin of safety. The Q400 aircraft have sensors to provide angle of attack information to the stall warning computer. They also provide information to display a low speed cue on the PFD (**Figure 1**). The top end of the low speed cue displays the speed at which the Stick Shaker stall warning will commence. The low speed cue will change its position relative to changes in wing loading as the aircraft banks or experiences turbulence gusts.

Other useful cues that can aid the pilot in avoiding a stall exist, however they are not installed on the Q400. One is an **angle of attack indicator**. As noted above, the aircraft is equipped to measure angle of attack and uses that information for some displays. However the "raw data" is not displayed to the flight crew. An angle of attack indicator can be an extremely useful tool to a crew, given proper training. It provides basic, unfiltered information directly related to the aerodynamic capability of the aircraft at that moment under all conditions. It displays actual angle of attack information to the pilot on the PFD or a separate instrument. This lets the pilot know the actual angle of attack and can alert the pilot to the aircraft's proximity to a stall. This can be especially useful when an aircraft is maneuvering, flying slow,

[17] [17] Operations Group Chairman's Factual Report – Addendum 1, Page 10
[18] Jetstream 31/32 and Jetstream 41

or is changing flap configuration. It can also alert a pilot that his plane's weight has been incorrectly calculated resulting in incorrect approach speed calculations.

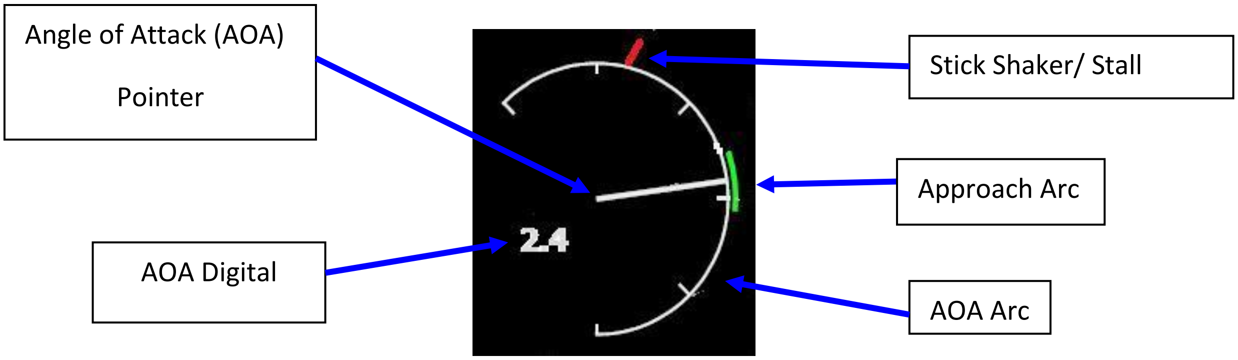

Figure 4- Angle of Attack Indicator

Pitch Limit Indicators (**PLI**) display the aircraft pitch attitude that will activate the stick shaker. The PLI is a moving indication on the artificial horizon display of the PFD. These pointers, or "eyebrows," display at high angles of attack and low airspeed above the pitch indicator of the airplane. These pointers move closer to the pitch display as the aircraft increases its angle of attack. They will touch the pitch cue at the same time the stick shaker activates. This gives the pilot direct feedback on the relationship of the aircraft's pitch to stall and advance indication of pending stick shaker activation. The most important benefit of a PLI is that it gives the pilot immediate direction during a stall on where to pitch the aircraft's nose to break or exit the stall.

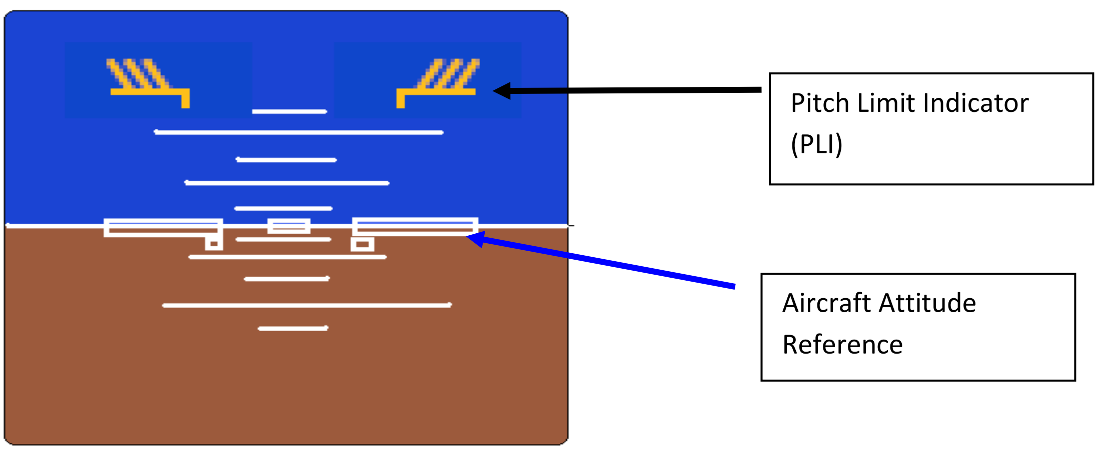

Figure 5- Pitch Limit Indicator

2.2.3.5 Autothrottles

The Q400 power levers must be set manually. This is not uncommon among regional jets and turboprops. However, almost all modern medium and large turbojet airliners have **autothrottles**. Speed selection utilizing auto throttles would have allowed the crew to set the target speed they were slowing to and then adjust thrust automatically to capture and maintain it. Many modern aircraft have α **(angle**

of attack) protection for stall protection. This allows automatic activation of the autothrottle system to recover airspeed if the aircraft gets too slow or near stall.

It is clear that activation of the stall warning is the last mode of defense and does not adequately protect the pilot from suddenly having to take control of the aircraft, with both surprise and distraction, while in a potentially hazardous state. Most of the warnings, alerts, indications and automatic functions described above would significantly reduce the likelihood of encountering a stall as well as enhance pilot awareness of the proximity to a stall, the actual stalled condition of the wing, and provide pitch information for recovery. Airframe design improvements such as counter rotating propellers would improve slow flight controllability and reduce the chance of spin entry. Aircraft such as the Q400 are designed and marketed for the regional airline industry. This coincidentally makes them likely “entry level” aircraft for low experience pilots. Thus, while many of the safety defenses described above are standard on sophisticated large turbojet aircraft that are most likely flown by high experience pilots, they are not installed on many of the turboprop or turbojets used by regional airlines. Some of these systems could be added by fairly minor hardware and or software improvements or options. Since cost is most likely the underlying factor in the lack of these safety improvements, it should be noted that requiring their installation on new designs or manufactured aircraft or retrofitting current airplanes would result in the most widely distributed cost benefit.

2.3 Colgan Air, Inc. Operations

Colgan Air, Inc, a wholly owned subsidiary of Pinnacle Airlines Corporation, is a regional airline headquartered in Manassas, Virginia. Colgan operates as Continental Connection, United Express, and US Airways Express. Colgan has been in operation since 1991 and now has more than 350 daily flights to 53 cities. Colgan originally flew only the Beech 1900C/D and subsequently added the Saab 340. In early 2008, the Q400 was added to the fleet at Colgan to fly as Continental Connection out of Newark-Liberty International Airport. The rapid growth of the airline should have been accompanied by an increase in the sophistication of its infrastructure, but the Operations portion of the NTSB investigation revealed shortcomings in this area that suggest the airline’s operating practices were not adequate to support the size of the operation. The airline was unable to accurately track crewmember experience and required training and could not provide the flight crews with comprehensive operating manuals for the aircraft in which they were expected to maintain proficiency.

2.3.1 Record Keeping

One of the important management functions of an airline is to ensure proper record keeping of their employees to ensure that their employees, specifically pilots, are current, legal, and qualified. These records provide the basis for ensuring that crewmembers have successfully completed their required training. They also help ensure that pilots do not fly more than the FAA legal requirements and obtain the FAA rest requirements. Colgan was approved by the FAA to use electronic record keeping for each crewmember, dispatcher, instructor, and check airman. During the investigation Colgan provided documentation for both the accident Captain and First Officer; however, some of the records specifically for the Captain, are inaccurate.

FAA records show that the accident Captain was disapproved for his initial airline transport pilot certificate on October 15, 2007, and was successful on his re-test October 18, 2007. According to Colgan's records in CrewQual[19], the accident Captain's unsuccessful checkride was on October 3, 2007 and subsequent successful checkride was on October 15, 2007.[20] The flight times provided by Colgan to the NTSB also show a variety of inconsistencies. According to Colgan's records, the accident Captain had 110.7 total hours in the Q400 and 116:02 in the past 90 days.[21] The past 90 days encompasses his entire experience on the Q400, so the total time on the Q400 and the time in the past 90 days should be the same. Colgan records also show that the Captain completed his 'Consolidation of Knowledge and Skills' on February 10th, 2 days prior to the accident. Consolidation of Knowledge and Skills means that the Captain would have completed 100 hours in the aircraft and based on Colgan's records, the Captain had 110.7 or 116:02 total hours in the Q400, depending on which number is accurate, and on February 11th the Captain only flew 5 hours. Even if some of the flying on February 10th was subsequent to the Captain reaching his 100 hours it would not add up to either 110.7 or 116:02.

While these inaccuracies were not causal to the accident they demonstrate Colgan's lack of compliance with FAA required basic management functions. Colgan's Internal Evaluation Program (IEP) should be designed to specifically identify these deficiencies and put in place procedures to ensure that these types of errors are not repeated. This does not appear to be functioning correctly at Colgan. This is not the first time that Colgan's IEP program has been found deficient. In December 2007, during the Department of Defense audit, they found the IEP program was not "up to snuff."[22] Colgan's Director of Safety stated that they corrected the errors discovered during the audit, but during the investigation it was discovered that the Manager of Internal Audit and Evaluation position has been open for at least 10 months.

2.3.2 Weight and Balance

Operations Specification A099 was issued to Colgan by the FAA on May 25, 2005. This program details the weights of passengers and bags. Colgan's approved program specified that for planning purposes at that time of the year each adult passenger was assumed to weigh 195 lbs. During the course of the investigation it was determined that fleet-wide Colgan was using 189 lbs for each adult.[23]

Weight and Balance is fundamental to an airline operation and in the past, inaccuracies with a weight and balance program have proven to be detrimental. An inaccurate weight and balance was partially responsible for the Air Midwest accident in January 2003. Subsequent to that accident the FAA revised its standards for developing a weight and balance program. These revised standards were used by Colgan to establish the average weight program discussed above. It is critical that an airline have in place a quality assurance program to pro-actively identify these errors and correct them before an event.

[19] CrewQual is part of a Sabre software suite used by Colgan to track training records of pilots and other employees
[20] Group Chairman's Factual- Operations Group, Page 5-6
[21] Group Chairman's Factual- Operations Group, Page 6
[22] Operations Group Chairman Interview Summary – Director of Safety Daryl LaClair, Page 19
[23] Group Chairman's Factual- Operations Group, Page 8

2.3.3 Manuals

Colgan pilots are provided a Company Flight Manual (CFM), along with the Colgan Flight Operations Policies and Procures Manual (FOPPM). The CFM for the Saab and the Q400 have two different manual philosophies. The Saab CFM is designed to be a standalone manual and is the only reference manual, which the Saab pilots need to operate the aircraft. The Q400 CFM on the other hand has been referred to as a suite of manuals.

The Q400 approved manual system at Colgan at the time of the accident included the CFM, but was also comprised of nine additional manuals (AOM Volume 1a, 1b, 2, 3, 4a, 4b, QRH, MEL, and the AFM). Federal Aviation Regulations requires certificate holders to prepare and keep current a manual for the use and guidance of flight…personnel[24] in conducting its operations, which is what Colgan did with its suite of manuals. The Regulations also require that each certificate holder furnish copies of the manual…or appropriate parts of the manual to…crewmembers[25]. Colgan did not issue these other manuals to the pilots[26] and they were only available on the flight deck.

The challenge with having a suite of manuals and only providing the CFM to each flight crew member is that many operationally significant procedures were omitted from the CFM. Flying in icing conditions is an example. The only reference in the CFM to operating in icing conditions and the use of the icing equipment was located in the CFM section 2.6.6 (Figure **6**) and contained no operational procedures, only limitations. In addition the bottom of the section alluded to a paragraph 4.7 OPERATION IN ICING CONDITIONS which was not in the CFM, but is located in the AFM.

2.6.6 ICE PROTECTION

ENGINE

Engine intake by-pass doors must be open for engine operation in icing conditions.

NOTE

Icing conditions exist when the SAT on the ground and for take-off is 10 °C or below, or SAT in flight is 5 °C or below, and visible moisture in any form is present (such as clouds, fog with visibility of one mile or less, rain, snow, sleet or ice crystals).

Icing conditions also exist when the SAT on the ground and for take-off is 10 °C or below when operating on ramps, taxiways or runways where surface snow, ice, standing water, or slush may be ingested by the engines or freeze on engines, nacelles or engine sensor probes.

AIRFRAME

When ice is detected, the AIRFRAME MODE SELECT selector must be positioned at FAST or SLOW. See paragraph 4.7, OPERATION IN ICING CONDITIONS.

Figure 6- Colgan Q400 CFM Paragraph 2.6.6

24 14 CFR 121.133
25 14 CFR 121.137
26 Operations Group Chairman Interview Summary –Manager Flight Standards Sheri Baxter, Page 56

The Bombardier AFM, on the other hand, had over four pages of critical operational information for pilots.

4.7.2 ICE PROTECTION PROCEDURES

4.7.2.1 TAKE-OFF IN OR INTO ICING CONDITIONS

PRE TAKE-OFF CHECKS

1. ENGINE INTAKE door switches – Press. Check OPN/HTR advisory lights illuminate.
2. WINDSHIELD HEAT:
   a. WINDSHIELD HEAT selector – NORM.
3. DEICE PRESS indicator – Check 18 ±3 psi on each dial.
4. PROP selector – ON. Observe PROPS advisory lights illuminate individually and go out in sequence, and the normal operating (green arc) on the OIL temperature indication on ED changes to 65 to 107 °C.

Figure 7- Bombardier AFM Paragraph 4.7.2 (Page 4-7-2)

AFTER TAKE-OFF

At 400 ft AGL; commencement of third segment:

1. Airspeed – Increase to Final Take-off Climb Speed (Figure 5–2–7) + 20 kt.
2. FLAPS lever – 0° at flap retraction initiation speed (Figure 5–6–11) flap 5° and 10° or (Figure 5–6–12) flap 15°.
3. REF SPEEDS switch – INCR. Check [INCR REF SPEED] appears on ED.

CAUTION

If airspeed is not increased before REF SPEEDS switch is selected to INCR, stall warning may occur.

4. For performance penalty, see Table 5–13–1.

At 400 ft AGL; continued second segment:

1. Airspeed – Increase to V_2 (Figure 5–2–2) flap 5° + 20 kt.
   – Increase to V_2 (Figure 5–2–4) flap 10° + 20 kt.
   – Increase to V_2 (Figure 5–2–6) flap 15° + 20 kt.
2. REF SPEEDS switch – INCR. Check [INCR REF SPEED] appears on ED.

CAUTION

If airspeed is not increased before REF SPEEDS switch is selected to INCR, stall warning may occur.

3. For performance penalty, see Table 5–13–1.
4. On initial detection of ice: AIRFRAME MODE SELECT selector – FAST.

At commencement of third segment:

5. Airspeed – Increase to Final Take-off Climb Speed (Figure 5–2–7) + 20 kt.
6. FLAPS lever – 0° at flap retraction initiation speed (Figure 5–6–11) flap 5° and 10° + 20 kt or (Figure 5–6–12) flap 15° + 20 kt.
7. See paragraph 4.7.2.3.

4.7.2.2 IN-FLIGHT – BEFORE ENTERING ICING CONDITIONS OR WHEN ICE IS DETECTED OR WHEN FLASHING "ICE DETECTED" ADVISORY APPEARS ON ED

1. ENGINE INTAKE door switches – Press. Check OPN/HTR advisory lights illuminate.
2. PROP selector – ON. Observe PROPS advisory lights illuminate individually and go out in sequence, and the normal operating (green arc) on the OIL temperature indication on ED changes to 65 to 107 °C.

NOTE

The effectiveness of the propeller deicing system can be improved and propeller vibration reduced by operation of the propellers at 1,020 rpm.

3. REF SPEEDS switch – INCR. Check [INCR REF SPEED] appears on ED.
4. WINDSHIELD HEAT:
   a. WINDSHIELD HEAT selector – NORM.

Figure 8- Bombardier AFM Paragraph 4.7.2 (Page 4-7-3)

If ice forms on the forward edge of pilot's side window:

1. PLT SIDE WDO/HT switch – ON.
2. DEICE PRESS indicator – Check 18 ±3 psi on each dial.

NOTE

1. To ensure deice pressure is maintained at 15 psi or greater during descent, holding and approach, it may be necessary to increase N_L by advancing the POWER levers.
2. For performance penalty, see Table 5–13–2.

4.7.2.3 CLIMB, CRUISE AND DESCENT IN ICING CONDITIONS

On initial detection of ice:

1. Minimum airspeed:
   a. Climb – Final Take–off Climb Speed (Figure 5–2–7) + 20 kts.
   b. Descend – 1.23 V_{SR} (Figure 5–1–2) flap 0° + 25 kts.
2. AIRFRAME MODE SELECT selector – FAST or SLOW, depending on the rate of ice accumulation. Check WING and TAIL advisory lights illuminate sequentially in pairs.

NOTE

Monitor ice accumulation between boot cycles to confirm that the selected AIRFRAME MODE rate (FAST or SLOW) is appropriate. When using the wing inspection lights, the inboard boot area only, visible from the cockpit, is sufficiently illuminated for assessing ice accumulation.

CAUTION

An accumulation of ice on the airplane may change the stall characteristics, stall speed, or warning margin provided by the stall warning system.

3. Monitor WING and TAIL advisory lights for normal operation.

When clear of icing conditions and all ice is removed from the visible leading edges:

4. AIRFRAME MODE SELECT selector – OFF.

When the aircraft is aerodynamically clean:

NOTE

The aircraft can be considered aerodynamically clean when all ice is removed from the visible leading edges and wing tips.

5. REF SPEEDS switch – OFF. Check [INCR REF SPEED] disappears on ED.
6. Minimum airspeed 1.23 V_{SR} (Figure 5–1–2) flap 0° or Approach and V_{REF} (Figures 5–8–1 through 5–8–3) flap 5°, 10° and 15°.

Figure 9- Bombardier AFM Paragraph 4.7.2 (Page 4-7-4)

4.7.2.4 HOLDING, APPROACH AND LANDING IN ICING CONDITIONS

NOTE

When holding in icing conditions flap must be at 0°.

On initial detection of ice:

1. Airspeed:
   - Minimum holding, 190 kt.
   - Approach Speed 1.23 V_{SR} (Figure 5–1–2) flap 0° + 25 kt.
   - Approach Speed (Figure 5–8–1) flap 5° + 20 kt.
   - Go-around Speed (Figure 5–8–1) flap 5° + 20 kt.
   - Approach Speed (Figure 5–8–2) flap 10° + 20 kt.
   - Go-around Speed (Figure 5–8–2) flap 10° + 20 kt.
   - Approach Speed (Figure 5–8–3) flap 15° + 20 kt.
   - Go-around Speed (Figure 5–8–3) flap 15° + 20 kt.
   - Landing V_{REF} (Figure 5–8–1) flap 10° + 20 kt.
   - Landing V_{REF} (Figure 5–8–2) flap 15° + 20 kt.
   - Landing V_{REF} (Figure 5–8–3) flap 35° + 15 kt.
2. AIRFRAME MODE SELECT selector – FAST. Check WING and TAIL advisory lights illuminate sequentially in pairs.
3. For performance penalty, see Table 5–13–2.
   For performance penalty for landing with abnormal flap (0° or 5°), see Table 5–11–1.

4.7.2.5 HOLDING, APPROACH AND LANDING AFTER FLIGHT IN ICING CONDITIONS

1. Minimum Airspeed – see Para. 4.7.2.4.
2. Continue to cycle boots on FAST until all ice is removed from visible leading edges.

When all ice is removed from visible leading edges:

3. AIRFRAME MODE SELECT selector – OFF.

NOTE

The aircraft can be considered aerodynamically clean when all ice is removed from the visible leading edges and wing tips.

When the aircraft is aerodynamically clean:

4. REF SPEEDS switch – OFF. Check [INCR REF SPEED] disappears on ED.
5. Minimum airspeed 1.23 V_{SR} (Figure 5–1–2) flap 0° or Approach and V_{REF} (Figures 5–8–1 through 5–8–3) flap 5°, 10° and 15°.

Figure 10- Bombardier AFM Paragraph 4.7.2 (Page 4-7-5)

4.7.3 FLIGHT IN SEVERE ICING

1. Autopilot — Disconnect immediately.

CAUTION

Be prepared for a possible roll force requirement by firmly holding the control wheel prior to disconnecting the autopilot.

2. Condition levers — MAX/1020.
3. POWER levers — Adjust as required to maximum continuous power (Figure 5—1—16).
4. Minimum airspeed — 190 kt IAS.
5. Exit severe icing conditions by changing altitude and/or course as required.

CAUTION

Avoid aggressive maneuvering.

When clear of severe icing conditions:

NOTE

It can be assumed that the airplane is no longer affected by the severe ice encounter when the ice accumulated on the flight compartment side window is removed. When visible, other surfaces, such as the propeller spinner and wing leading edges aft of the deicer boots, should also be used to confirm that the ice accumulated during the severe icing encounter has cleared.

6. POWER levers and Condition levers — Adjust as required.
7. Airspeed — As required.
8. Autopilot — As required.

CAUTION

Prior to engaging the autopilot, ensure that in wings level steady state flight, there is no abnormal roll control force and the required lateral trim is appropriate for the aircraft configuration.

9. Refer to paragraph 4.7.2.4 or 4.7.2.5 as appropriate, for holding, approach and landing.

If it cannot be determined that the aircraft is no longer affected by the severe icing encounter:

10. Refer to paragraph 4.7.2.4 for holding, approach and landing.
11. Do not engage autopilot.

Figure 11- Bombardier AFM Paragraph 4.7.2 (Page 4-7-6)

The result of this discrepancy is that Bombardier provides a large amount of detail on the specifics of safe operation in icing conditions, but Colgan's policy of having this detailed information only available on the flight deck makes it impossible for crews to review and study the information other than in flight.

Additionally, some information that is in the CFM contradicts the manufacturer's recommendations in the AFM. In Figure **6**, the Colgan Q400 CFM says that the Airframe Mode Selector can be operated in either FAST or SLOW, but in the manufacturer's AFM under After-Takeoff in **Figure 8** it states that Airframe Mode Selector should be placed in the FAST position, this is the same guidance given in **Figure 10** for holding, approach, and landing in icing conditions.

In addition to providing incomplete and contradicting information to its crews, Colgan manuals are also ambiguous. The FOPPM states that checklists are challenge-response unless directed by the CFM.[27] It

[27] Colgan Air, Inc. FOPPM Page 5-34

further states that "[a]dditional checklist philosophy relating to Colgan policies and procedures are located in the aircraft CFM." As stated in the Operations Group Chairman Factual, there is no such statement of checklist philosophy, although the Climb and After Landing checklists are not challenge-response, but are completed silently.

The Colgan Q400 CFM also provides profiles for crews to follow for a variety of normal flight regimes, including take-off, approaches with vertical guidance, approaches with no vertical guidance, missed approach, landing, and holding. These profiles are pictorial depictions of each maneuver and include a few notes (**Figure 2, Figure 12**).

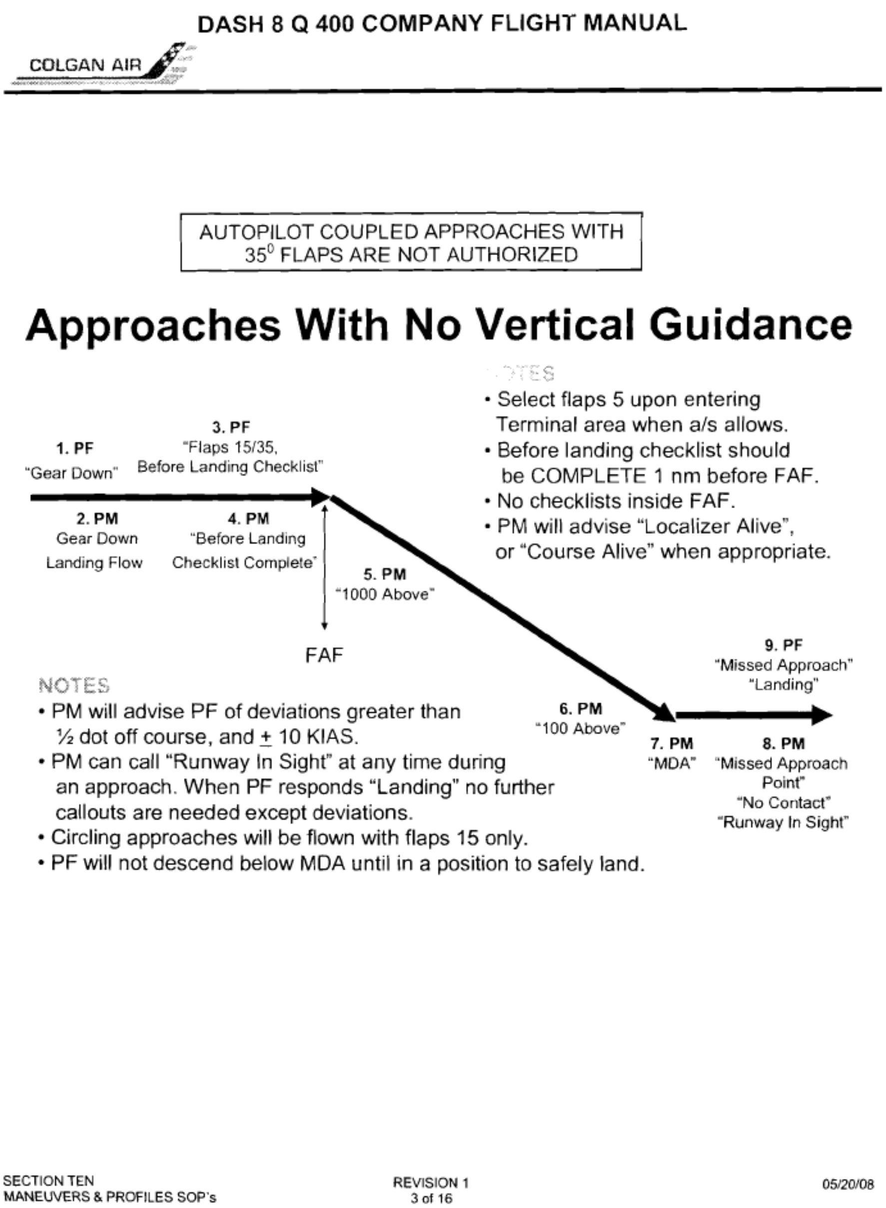

Figure 12- Colgan Q400 CFM (Section 10 Page 3)

The profiles do not provide basic milestones for crews on the approach and are very vague based on the depiction as to when key sequences (Gear and Flap Extension) should occur. This ambiguity poses the hazard of unstabilized approaches and leads to non-standard operations. To evaluate industry standardization on providing crews information for various profiles, ALPA examined several exemplar manuals including a Boeing 777, CRJ-200, and DHC-8-200. Each of these manuals provide both a pictorial and expanded textual depictions of how a crew should fly each maneuver including at what point on the approach the gear should be extended, as well as flaps. In addition to this lack of guidance the CFM also fails to provide crew members with target or minimum airspeeds to fly based on the respective flap setting. The only airspeed guidance provided is the V_{ref} or $V_{ref(ICE)}$. Additionally, Colgan provides no guidance in determining V_{app} speeds even though the approach airspeeds to be flown in icing conditions from **Figure 10** references a V_{app}.

2.3.4 Crew Training

Colgan provided pilots with FAA approved ground, simulator, and operating experience training. Colgan originally contracted their training with Flight Safety, but over time transitioned to Colgan instructors and designated examiners. While the training was FAA approved, the investigation revealed major deficiencies in its training program.

2.3.4.1 Approach to Stall Training

Colgan pilots were exposed to three approach to stall scenarios during Q400 training: clean, take-off, and landing. The required maneuvers and standards for these procedures are detailed by the FAA in the ATP Practical Test Standards (PTS). Colgan documented the procedure for entry and recovery from these maneuvers in the interim CFM. They utilized a single profile depiction for each approach to stall.

These depictions were inadequate in several ways. The title of the depictions was not prefaced by the term “Approach to” (e.g. “Landing Stall” **Figure 13**). This could have implied it was a recovery procedure for a stall itself. The actual recovery cue required by the PTS is to recover at the first indication of an impending stall (buffeting or stick shaker). The Colgan profiles provided no such recovery cue. Colgan only instructed its pilots to “maintain altitude and heading” and demonstrated this by using a straight-line example for its profile (**Figure 13**). As was previously discussed in 2.3.3, there were only a few notes associated with the “approach to stall” depiction, there were no expanded text to tell pilots what additional procedures must be accomplished. An example of this would be for the Pilot Flying (PF), the only guidance was “Advance PL to Rating Detent”, “Gear Up” and “Flaps 0,” there were no additional descriptions on how to recover. There is no mention or discussion of an actual stall event. A stall results from exceeding the critical angle of attack and to fully recover from a stall the angle of attack must be reduced. Another issue with the Colgan stall recovery procedure pertains to the Pilot Monitoring responsibilities. Although the Pilot Flying states “check power” during the recovery, the recovery profile did not define what the Pilot Monitoring should be “checking” or doing with the Power Levers. The recovery profile does not require the Pilot Monitoring to verbalize the power levers have reached the desired power setting. The recovery procedure does not require the Pilot Monitoring to advise the Pilot Flying the state of the aircraft and status of the stall recovery by making call outs regarding pitch attitude, airspeed trend, and altitude. The recovery procedure does not give pilots pitch recommendations that may be required during an actual stall recovery. During the Public Hearing, Q400 Chief Simulator Instructor, Paul Pryor stated over and above what is on the Colgan stall profile, Colgan does not provide specific training to the Pilot Monitoring during a stall event.[28]

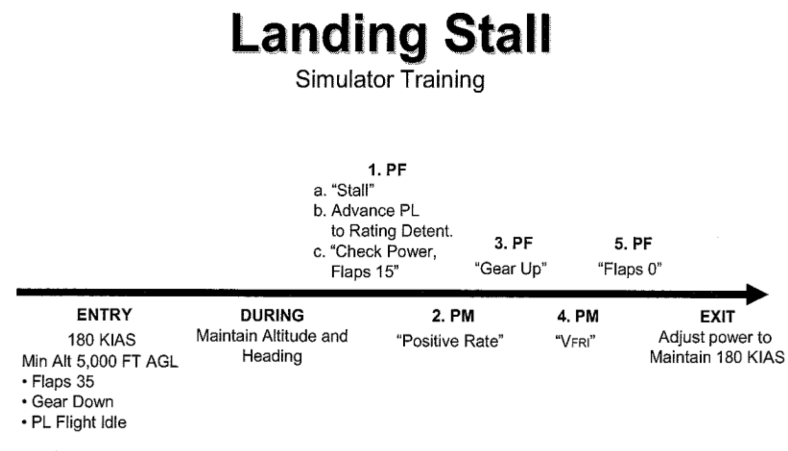

Figure 13- Colgan Q400 CFM (Section 10 Page 9)

Another deficiency was that the procedures and training were not done in accordance with the FAA ATP PTS. Each of these scenarios were conducted in the simulator at 5000' MSL and these maneuvers were typically accomplished as a "warm-up"[29] to the simulator session. The Airline Transport Pilot (ATP) Practical Test Standards (PTS) defined the standards and the scenario to be used to evaluate each maneuver during a checkride. The ATP PTS for Approaches to Stall (**Figure 14**) specifically defined the recovery standards in Item 6. The PTS also stated in Item 2 of **Figure 14** that "[w]hen accomplished in an FTD or flight simulator, the entry altitude should be consistent with the expected operational environment for the stall configuration." The Landing Stall maneuver (**Figure 13**) should have been trained and evaluated during an approach to landing scenario. For example, the aircraft fully configured for landing on final approach, close to the ground. The other two approach to stall profiles should have been conducted in their specific regimes of flight, as well. This would have included conducting at least one approach to stall at an altitude representative of an intermediate or final instrument approach altitude. This was not being conducted at Colgan. Crews trained in this manner lose the association of the maneuver being trained with its true operational relevance. Thus, when confronted with an actual approach to stall scenario during a night IMC flight, the crew had never been exposed to this situation before.

Colgan had seen similar situations in the simulator and had not taken any corrective action or provided a heightened awareness to crews. For example, a Colgan Check Airman stated, "[t]ypically, they're distracted by something else or they typically forget. I've given plenty of PC checkrides and one area that

[28] Colgan Air, Inc. Flight 3407 Public Hearing Day 1, Page 155
[29] Colgan Air, Inc. Public Hearing Day 3, Page 703

I always see a lot is when they do the circle to JFK, they hit the final approach fix, the pull the power back to idle, they're coming down 1,000 feet a minute and right about 1,000 feet they are breaking up [sic], there's the runway, the autopilot levels off the airplane and they're looking at the runway, they begin to think about the circle and they forget to bring the power up, and they miss the ball. The next thing you know, a stick shaker comes on."[30]

B. TASK: APPROACHES TO STALLS

REFERENCES: 14 CFR part 61; FAA-H-8083-3; FSB Report; POH/AFM.

THREE approaches to stall are required, as follows (unless otherwise specified by the FSB Report):

1. One in the takeoff configuration (except where the airplane uses only zero-flap takeoff configuration) or approach (partial) flap configuration.
2. One in a clean cruise configuration.
3. One in a landing configuration (landing gear and landing flaps set).

CAUTION: Avoid deep stalls which are termed as "virtually unrecoverable" in airplanes, and "tip stalls" in swept wing airplanes.

One of these approaches to a stall must be accomplished while in a turn using a bank angle of 15 to 30°.

Objective. To determine that the applicant:

1. In actual or simulated instrument conditions exhibits satisfactory knowledge of the factors, which influence stall characteristics, including the use of various drag configurations, power settings, pitch attitudes, weights, and bank angles. Also, exhibits adequate knowledge of the proper procedure for resuming normal flight.
2. Selects an entry altitude that is in accordance with the AFM or POH, but in no case lower than an altitude that will allow recovery to be safely completed at a minimum of 3,000 feet AGL. When accomplished in an FTD or flight simulator, the entry altitude should be consistent with expected operational environment for the stall configuration.
3. Observes the area is clear of other aircraft prior to accomplishing an approach to a stall.
4. While maintaining altitude, slowly establishes the pitch attitude (using trim or elevator/stabilizer), bank angle, and power setting that will induce a stall.
5. Announces the first indication of an impending stall (such as buffeting, stick shaker, decay of control effectiveness, and any other cues related to the specific airplane design characteristics) and initiates recovery (using maximum power or as directed by the examiner).
6. Recovers to a reference airspeed, altitude and heading with minimal loss of altitude, airspeed, and heading deviation.
7. Demonstrates smooth, positive control during entry, approach to a stall, and recovery.

FAA-S-8081-5F 2-16

Figure 14- Airline Transport Pilot Practical Test Standards (FAA-S-8081-5F) July 2008

[30] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 72

The FAA ATP PTS required that the applicant should recover with a minimal loss of altitude. The Colgan Stall Profiles, however, required a pilot to maintain altitude. In addition, Colgan Check Airmen were not evaluating to the FAA ATP PTS. Three Colgan check airmen[31,32,33] incorrectly stated that the PTS standard for recovery during approaches to stalls was ±100'. As a result of improper training due to incorrect interpretation of the PTS by Colgan instructors, Colgan pilots' approach to stall recovery techniques were negatively affected. Colgan pilots are on record stating they would need to hold or increase pitch attitude and maintain altitude during a recovery or risk failure of the checkride. Another Colgan Check Airman stated, "initially relax pressure on the yoke and then were trying for 10 degrees pitch attitude."[34] A Colgan First Officer, described recovery pitch attitude as, "hold 4 degrees or possible just at horizon to prevent altitude loss."[35] Other Colgan pilots also described a variety of pitch-up recovery techniques.[36,37]

There is no FAA requirement nor is there any indication of a Colgan requirement to train approach to stalls with the Reference Speeds switch in the INCR position. This does not provide pilots experience with recovering from an approach to stall in icing conditions. In the case of the Q400, pilots would not be exposed to stalls with the low speed cue advanced up the airspeed tape, as it is with the Reference Speeds switch in the INCR position.

The approach to stall training provided by Colgan led to a situation in which crews who inadvertently encountered a fully developed, low altitude stall found themselves in a flight environment in which they had not received training. Additionally, the Reference Speeds switch placed in the INCR position would change shaker speed and therefore change recovery speed. The possible illumination[38] of GPWS "Pull Up" light would provide a distracting and conflicting warning, as well. This would create multiple, potentially conflicting inputs that must be reconciled quickly by an inadequately trained crew.

Each Colgan stall profile is an "approach to stall" followed by an "approach to stall" recovery. This is the only maneuver relating to stalls required by the FAA for airline training. Recognition and recovery from fully developed stalls were not a part of the Colgan stall training profile, and are unlikely to be found in any airline training . The crews were not provided any practical training on recovery from a full stall. "Stall recovery requires lowering the nose of the airplane to reduce the angle of attack while simultaneously adding power and then smoothly applying elevator control to recover to level flight."[39] Recognition and recovery from fully developed stall is required during basic instruction for private and commercial airmen certificates. This may be the last time airline pilots receive actual stall training in their careers.

[31] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 15
[32] Operations Group Chairman Interview Summary – Q400 Check Airman Scott Moberly, Page 66
[33] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 47
[34] Operations Group Chairman Interview Summary – Q400 Check Airman Dean Nitsos, Page 28
[35] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 6
[36] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 21
[37] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 32
[38] Flight Data Recorder - 10 Addendum 1
[39] Operations Group Chairman's Factual Report – Addendum 3, Attachment 8

2.3.4.2 Stall Training

The Stick Pusher on the Q400 is designed to normally activate after stall entry. It applied a forward force of approximately 70 pounds to the control column during a stall event. It was described by Bombardier as both a warning and recovery device. Approach to stall recovery requires recovery before actual stall. Therefore a pilot would not normally encounter stick pusher activation during approach to stall training. At the time of the accident, Colgan did not provide stick pusher training in the aircraft or simulator, nor were they required to do so. During the course of the investigation a few instructors stated that they had demonstrated the stick pusher operation to their students. However the accident Captain's instructor stated that the Captain had not received a stick pusher demonstration or training.[40] During the Public Hearing, the Q400 Chief Simulator Instructor stated pilots in the Saab 340 training program did receive stick pusher training, so the Captain would have been exposed to that during his Saab 340 training. Anecdotal evidence from several Colgan pilots asserted that although stick pusher training was part of the syllabus, the syllabus typically was not followed. Instead pilots were trained on the maneuvers listed on a training form[41], on which stick pusher was not included.

Letting the stick pusher "do its job" when it activates involves a conscious effort by the pilot not to intervene when the control column is forcibly pulled away. This is counter-intuitive. Therefore, providing stick pusher training to pilots is essential to assure correct action should the stick pusher activate. A Check Airman stated that 75% of the pilots that he had demonstrated the stick pusher operation to had pulled back against the pusher.[42] Additionally in the Public Hearing for the Pinnacle 3701 accident in Jefferson City, Missouri, a Bombardier training pilot stated that some of the pilots he has seen when faced with a stick pusher scenario in the simulator are "…scared, and they don't know what to -- how to react, what to do. So, the proper training is -- is a huge factor, to make sure that if you end up on a pusher, this is what you need to do."[43]

2.3.4.3 Simulator Fidelity

Simulator training in stick pusher and full stall recognition and recovery are essential in producing a fully competent airline pilot. As important as this training may be, it may not be arbitrarily added to a syllabus. A limitation to this training in the simulator is simulator fidelity in this aerodynamic regime. If the simulator fidelity is inadequate, the training will be similarly inadequate. Mr. Piyush Gandhi, Director of Flight Operations at Porter Airlines has firsthand experience stalling the Q400 from his time spent with Bombardier and noticed the real airplane contrasted significantly with the simulator pusher forces.[44] Flight Safety also echoes the lack of simulator fidelity during certain maneuvers. During the Operations/Human Performance group visit to Flight Safety Toronto the group was instructed that maneuvers conducted outside those contained in the AFM would exceed the simulator's capabilities to

[40] Operations Group Chairman Interview Summary – Q400 Check Airman Wayland Kramer, Page 60
[41] Operations Group Chairman Pilot Training Form from 2003 Colgan Accident
[42] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 16
[43] Operations Group Chairman NTSB Letter to FAA Regarding Recommendations A-07-01 to A-07-11 January 23, 2007, Page 4
[44] Operations Group Chairman's Factual Report – Addendum 3, Attachment 4

realistically model the event.[45] This simulator fidelity issue has been discussed prior to this accident, however no progress seems to have been made towards resolving the issue. In 2007, Gerald M. Baker observed that most simulators are not programmed with data that accurately reflects actual aerodynamic stalls or pusher activation. Baker believes this data could be incorporated in new simulators and retrofitted on older simulators over time.[46] Simulator fidelity must be improved if stall training is to be effective and realistic. In the mean time, simulators should be assessed to determine if sufficient fidelity exists to at least teach basic full stall recognition and recovery procedures.

2.3.4.4 Tailplane Icing Stall Training

There have been a number of accidents attributed to the adverse affects of flight in icing conditions causing the aircraft to depart controlled flight. Turboprop regional aircraft tend to be operated on shorter flights offering fewer routing and altitude options causing them to spend a disproportionately high amount of time exposed to icing relative to other types of airline operations (Federal Aviation Administration- Aircraft Certification Service; Northwest Mountain Region, 1992). The relatively smaller size of these aircraft increases the sensitivity of their flight characteristics to ice accumulation, as the aircraft size increases the relative effect of ice thickness or roughness decreases. (Federal Aviation Administration, 2007) Not only is there an increased sensitivity to ice accumulation, but smaller and thinner airfoils tend to be more efficient at ice accretion. This combination of risk factors is important to note because many icing-related accidents have been attributed to pitch or roll upsets due to the flight controls being located in areas where the airfoils are the most susceptible to ice accretion. An aircraft's tailplane exemplifies this scenario because it is ordinarily thinner than the wing thereby making it a more efficient collector of ice (Federal Aviation Administration, 2007). The tailplane aerodynamically opposes the wing to balance the effect of the center of gravity being forward of the center of lift.[47] Tailplane icing becomes dangerous when ice accumulation, which cannot be observed by the pilot, becomes severe enough to disrupt the airflow over the tailplane causing it to aerodynamically stall thereby allowing the aircraft to pitch over uncontrollably as illustrated in **Figure 15**.

[45] Human Performance Group Chairman's Factual Report Addendum 1, Page 7
[46] Operations Group Chairman's Factual Report – Addendum 3, Attachment 8
[47] Colgan Air, Inc. Public Hearing Day 1, Page 32

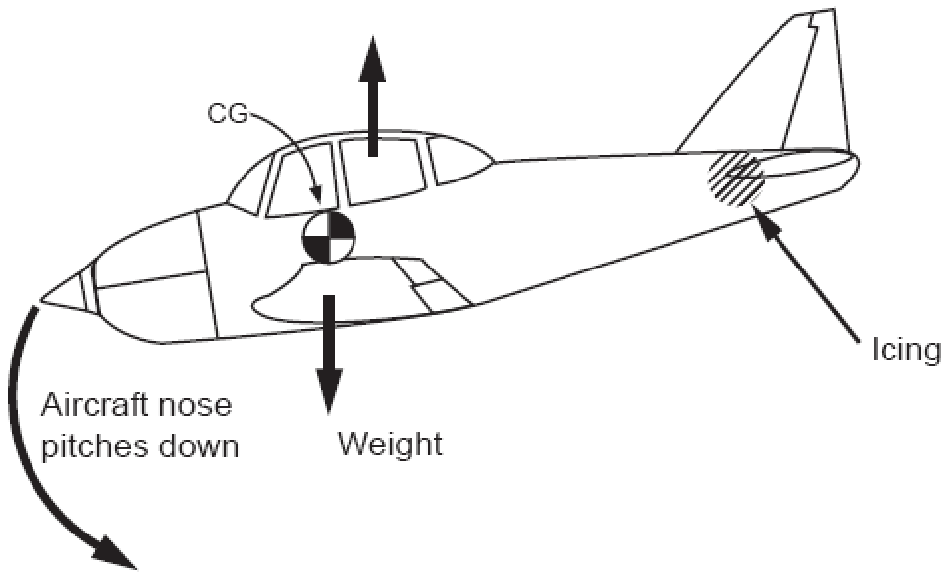

Figure 15- Pitch Over Due To Tailplane Stall (Federal Aviation Administration, 2007)

During the Public Hearing, Mr. Don Stimson stated the FAA's position is that tailplane stall susceptibility is unacceptable as it is considered an unsafe condition.[48] This illustrates the changes in aircraft certification that have taken place as the result of research generated by the icing induced upset accidents of the past. Mr. Paige, from Bombardier, stated that Bombardier designed the Q400 with tailplane icing in mind and there have been no reports of tailplane stalls.[49] Improved certification standards have made these events rare, however it is possible for an aircraft to encounter significant icing conditions that exceed the certification standards (Federal Aviation Administration, 2007). It is for this reason, as Mr. Ratvasky suggested during the hearing , that pilots should be trained on the aerodynamic affects of icing *including the particular characteristics of their aircraft* (emphasis added).[50]

Colgan showed the video "NASA In-Flight Icing Training for Pilots" as part of the winter operations training making pilots familiar with some of the dangers of flight in icing to include roll upset and tailplane stall.[51,52] NASA used the DHC-6 Twin Otter as the test aircraft for the video. Although it may look similar in appearance to the Q400 and many of the general recommendations apply, there are significant differences in the flight control systems between this aircraft and the Q400 flown by Colgan. During the course of the investigation the Operations group conducted numerous interviews, which included the topic of tailplane icing. It became apparent that effective training had not been accomplished since most of the pilots did not recognize the differences between the general issues discussed in the video and those which were actually pertinent to the Colgan fleet. These should have

[48] Colgan Air, Inc. Public Hearing Day 1, Page 136
[49] Colgan Air, Inc. Public Hearing Day 1, Page 121
[50] Colgan Air, Inc. Public Hearing Day 1, Page 130
[51] Operations Group Chairman Interview Summary – Ground School Instructor Andrew Nagle, Page 21
[52] Group Chairman's Factual- Operations Group, Page 38

been addressed in the Colgan winter operations training as a supplement to the NASA video. When asked to describe handling characteristics indicating an imminent tailplane stall the pilot comments included "a lightening of the pitch controls"[53], "controls get a little mushy,"[54] and "you'd feel it with your hands."[55] These statements are accurate for the Twin Otter in the NASA training video and for the Saab, but both of those aircraft have reversible pitch control systems. The Q400 does not. This may have resulted in negative transfer of knowledge from previously flown aircraft or an incomplete understanding of aircraft differences. The Q400 has a hydraulically-powered, irreversible elevator and an artificial feel system that prohibits the pilot from receiving these sensations.[56] Aircraft with irreversible controls would give little, if any, sensation prior to the aircraft pitching nose down.[57] This training issue becomes even more misleading considering the AOM includes emergency/abnormal guidance for operating in icing conditions which refers to stick force lightening or irregularities being a precursor to tail stall.[58] During the public hearing Mr. Paige clarified that this AOM reference is incorrect due to the irreversible controls.[59]

The confusion in stall recognition is best illustrated by one Colgan Captain's remarks, as interviewed by the Operations group in Buffalo, when he said that it would be hard to tell the difference between the wing and tail stall with the stick shaker going.[60] FAA Aircrew Program Manager Michael Jessie raised the fact that the NASA video does not address aircraft with stall protection systems such as the stick shaker on the Q400.[61] He continued to state that the scenario of a nose down pitch associated with a stick shaker is not addressed, however he correctly surmised that if the stick shaker activates it is indicative of a wing stall and that would be the appropriate recovery procedure to apply.[62] The activation of the stick shaker in regards to icing should have been pointed out in the winter operations training as an aircraft-specific supplement to the NASA video. As Mr. Martin stated in the public hearing, the stick shaker is a stall warning and would not normally occur in a tailplane stall.[63] Most of the pilots interviewed characterized it as hard to distinguish between the two types of stalls. Given the lack of cues sensed through the flight controls and misunderstanding of the stick shaker activation relating to tailplane icing, the pilot is faced with relying on the flight conditions and aircraft configuration alone to distinguish between the type of stall and thus the appropriate recovery. Flight conditions conducive to a tailplane stall would be flight in significant icing conditions and extending the flaps, particularly from an intermediate flap setting to full flaps or at speeds near the flap limit speed. The main factor in driving

[53] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 20
[54] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 69
[55] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 37
[56] Colgan Air, Inc. Public Hearing Day 1, Page 45
[57] Colgan Air, Inc. Public Hearing Day 1, Page 91
[58] Bombardier Q400 Dash 8 AOM Volume 1, Abnormal and Emergency Procedures Page 3.4-24
[59] Colgan Air, Inc. Public Hearing Day 1, Page 132
[60] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 22
[61] Operations Group Chairman Interview Summary – FAA Aircrew Program Manager Michael Jessie, Page 37-38
[62] Operations Group Chairman Interview Summary – FAA Aircrew Program Manager Michael Jessie, Page 37-38
[63] Colgan Air, Inc. Public Hearing Day 1, Page 116

the tailplane towards stall is flap deflection, the more flap extended, the greater propensity for a tailplane stall to occur, as Mr. Ratvasky stated.[64]

Timely recognition of which type of stall is occurring is imperative in executing the appropriate recovery. Either condition is extremely dangerous at low altitudes. The procedure to recover from a tailplane stall is almost the exact opposite of that for a wing stall. Typically occurring during approach, a tailplane stall could result in a downward pitch that the pilot is unable to recover from; a point Captain Jack Wohner found particularly memorable from the NASA video.[65] Although airframe ice accumulation could result in a wing stall at significantly higher speed than ordinarily observed, it is considered a low speed event. The recovery would include releasing back pressure on the yoke, increasing the power to full and once airspeed is recovered retracting the landing gear and flaps. The tailplane stall would be associated with a relatively high speed and cause a downward pitching moment. To recover from it the pilot would retract flaps to the previous setting and apply backpressure on the yoke to counter the pitching moment.[66,67] The recovery from a tailplane stall if incorrectly applied to a wing stall would aggravate the condition. As the flaps retract the risk of a secondary stall increases because the speed might be too slow for the reduced flap configuration.[68]

Although the autopilot is prohibited from use in severe icing conditions,[69] it can significantly help the pilots manage cockpit workload at various stages of flight. It can also do the opposite. Dr. Dismukes stated "[y]ou can reduce your workload by intelligent use of automation or you can make it worse and get yourself into trouble by using it the wrong way."[70] Pilots must constantly decide what the appropriate level of automation is to be used at the appropriate time. Flying at night, in instrument conditions, requires increased vigilance in monitoring of the aircraft instruments. Autopilot usage significantly reduces the pilot workload in this respect and allows the pilot to devote more attention to tasks such monitoring systems like de-ice equipment, navigation, communications, checklists and aircraft configuration changes. The crew flying the Q400 is tasked with managing a mixed mode of automation; the autopilot can control pitch, roll and yaw, but the crew must simultaneously manage power settings. During high workload phases of flight, such as descent and approach much more attention needs to be given to managing the autopilot and the aircraft flight path. This leaves the crew in a position where more of their monitoring duties are significantly increased for managing the aircraft state while reducing their ability to monitor other cockpit tasks. Often the crew is even further challenged by having to accomplish these tasks at a faster pace than the normally expected or trained profile. This may cause the crew to put the aircraft into a high drag configuration, requiring even more of their attention to be placed on manipulating the autopilot or to lower the level of automation in use by hand flying the airplane. Dr. Dismukes discussed some of these limitations in automation use, "… it

[64] Colgan Air, Inc. Public Hearing Day 1, Page 37
[65] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 50
[66] Group Chairman's Factual- Operations Group, Page 39
[67] Colgan Air, Inc. Public Hearing Day 1, Page 36
[68] Colgan Air, Inc. Public Hearing Day 1, Page 148
[69] Group Chairman's Factual- Operations Group, Page 19
[70] Colgan Air, Inc. Public Hearing Day 3, Page 594

puts us a step away from the system, and that makes monitoring even more challenging."[71] The pilot must balance the use of the autopilot to manage cockpit workload against the tendency of the autopilot to mask the effects of icing on the airplanes flight characteristics. Although the Q400 elevator is irreversible the ailerons are not, thus still subject to the handling cues, potential roll upset as well as many other adverse conditions as described in the NASA video. The FAA gives further guidance on autopilot usage in AC 91-74A (**Figure 16**). Although this example is for cruise flight, the risk of an unexpected autopilot disconnect due to icing becomes especially hazardous in the low altitude approach environment.

> **f.** Again, care should be exercised when using an autopilot in icing conditions, while in cruise, just as in other phases of flight. When the autopilot is engaged, it can mask changes in handling characteristics due to aerodynamic effects of icing that would be detected by the pilot if the airplane were being hand flown. In an aircraft that relies on aerodynamic balance for trim, the autopilot may mask control anomalies that would otherwise be detected at an early stage. If the aircraft has non-boosted controls, a situation may develop in which autopilot servo-control power is exceeded. The autopilot disconnects abruptly, and the pilot is suddenly confronted by an unexpected control deflection.
>
> **g.** Pilots may consider periodically disengaging the autopilot and hand flying the airplane when operating in icing conditions. If this is not desirable because of cockpit workload levels, pilots should monitor the autopilot closely for abnormal trim, trim rate, or airplane attitude. As ice accretes on aircraft without autothrottles, the autopilot will attempt to hold altitude without regard for airspeed, leading to a potential stall situation.

Figure 16- Icing Considerations For Cruise (Federal Aviation Administration, 2007)

The following statement is taken from the Advisory Circular 91-74A, Pilot Guide: Flight In Icing Conditions published by the FAA:

> **d.** Accident statistics reveal that the majority of icing-related accidents occur in the final phases of flight. Contributing factors are configuration changes, low altitude, higher flightcrew workload, and reduced power settings. Loss of control of the airplane is often a factor. The ice contamination may lead to wing stall, ice-contaminated tailplane stall (ICTS), or roll upset.

Figure 17- Icing Considerations For Approach And Landing (Federal Aviation Administration, 2007)

Colgan flight 3407 shares many similarities to these conditions. Icing may not have been a significant factor in the upset in terms of aircraft performance; however, based on their training it was in the mindset of the crew. The CVR transcript details conversation in the six minutes prior to the autopilot disconnect in which the crewmembers discussed the ice accumulation on the airframe using phrases such as "… it's lots of ice" and "–most ice I've seen on the leading edges in a long time."[72]

[71] Colgan Air, Inc. Public Hearing Day 3, Page 579
[72] Cockpit Voice Recorder Group Chairman Factual Report, Page 12-56

The crew also talked about their previous experience in icing conditions, likely indicating concern over the conditions as Dr. Dismukes noted, "…you have a sense that, well, okay, it's all right. Now this is routine, but I haven't been here before and I would have liked to have had more exposure."[73]

This concern could bias their perceptions and decisions later in the event.[74] The crew actions in attempting to recover from the stall were very similar to those of a tailplane stall recovery.

It appears that the crew of flight 3407 did not recognize the condition they were in. This was summarized concisely by Dr. Dismukes who said, "[i]n this case, I don't see any evidence that he ever understood the situation he was in. I mean he knew something was wrong, but I don't know if he ever finally said, wait a minute. I've got to get the nose down no matter where I am."[75] When confronted with the stick shaker, the crew was experiencing an event they had not seen before and likely did not know how to react. Certainly there is reason to believe that icing was in the crew members mind set. First Officer Shaw completed winter operations as part of her recurrent training only six weeks prior to the accident[76] and the pilot interviews conducted during the investigation indicate inadequate aircraft specific training to supplement the NASA video. The interviews also indicate some confusion over tailplane stall recognition and recovery procedures. The actions of the crew in this event correlate to a tailplane stall recovery in that the pilot flying applied back pressure and the pilot monitoring retracted the flaps immediately. General knowledge such as that provided by the NASA video are helpful; however, it must be supplemented by aircraft specific training to include handling characteristics, susceptibility, recognition and recovery procedures, and for the accident crew it was not.

There is a "startle response" effect when pilots are confronted with unexpected situations, which relates to training and experience. Dr. Dismukes described this as,"…if it's something we rarely see and haven't practices to the level of automaticity, then we have to do a control processing, and even though we know theoretically in our declarative memory, yeah, I know the procedure for this, it would be like looking it up in a book, and we would be flailing around trying to find the right page, our brain may settle on something that seems like the situation but is, in fact, not, and we may execute the wrong response."[77] This crew did not properly recognize the type of stall first encountered when the stick shaker activated. The automatic response should have been to perform a wing stall recovery; however, if the scenario is not repeated enough in training or in practice it does not become an automatic response, thus the response becomes uncertain.

2.3.4.5 Crew Resource Management Training

Crew Resource Management, or CRM, is an FAA-mandated module in training and should provide pilots with the skills they need to effectively use the resources available to them. These skills include Leadership, Adaptability, Assertiveness, Communication, Decision Making, and Situational Awareness. The challenge, according to experts in the field, is to continue to enhance a CRM program, which will

[73] Colgan Air, Inc. Public Hearing Day 3, Page 596
[74] Colgan Air, Inc. Public Hearing Day 3, Page 608
[75] Colgan Air, Inc. Public Hearing Day 3, Page 606
[76] Group Chairman's Factual- Operations Group, Page 38
[77] Colgan Air, Inc. Public Hearing Day 3, Page 583

foster additional skill development and expose crew members to a wide variety of scenarios. CRM training focuses on “making use of all available resources and sometimes provides general guidance on workload management”, but rarely addresses the specifications and management of undesired aircraft states (Dismukes, Loukopolous, & Barshi, 2009, p. 68).

CRM is the effective use of all available resources for flight crew personnel to assure a safe and efficient operation, reducing error, avoiding stress and increasing efficiency. CRM was developed as a response to insights into the causes of aircraft accidents gathered from advances in investigative tools. Information gathered during investigations suggested that significant factors in many accidents were not technical malfunctions, poor aircraft handling skills or a lack of technical knowledge on the part of the crew. Rather, robust investigation revealed an inability of crews to respond appropriately to the situation in which they find themselves. For example, inadequate communications between crew members and other parties could lead to a loss of situational awareness, a breakdown in teamwork in the aircraft, and ultimately to a wrong decision or series of decisions which result in a serious incident or accident. In this accident, a loss of situational awareness led to mismanagement of an undesired aircraft state.

The widespread introduction of the dynamic (i.e. full motion) flight simulator as a training aid allowed various new theories about the causes of aircraft accidents to be studied under experimental conditions. On the basis of these results, and in an attempt to remedy the apparent deficiency in crew skills, additional training in flight deck management techniques should be a requirement for airlines.

CRM is concerned not so much with the technical knowledge and skills required to operate an aircraft but rather with the cognitive and interpersonal skills needed to manage the flight within an organized aviation system. It is nevertheless a learned skill, pilots do not exercise good CRM simply by virtue of having had flight instruction; it is a skill that is learned through initial and recurrent exposure to both theory and practice. In the context of CRM, cognitive skills are defined as the mental processes used for gaining and maintaining situational awareness, for solving problems and for taking decisions. Interpersonal skills are regarded as communications and a range of behavioral activities associated with teamwork. In this accident, the effectiveness of CRM was degraded.

Classroom training in CRM must be provided in conjunction with simulator revalidation training. Of particular importance is its integration with Line Oriented Flight Training (LOFT), which involves response to realistic scenarios where the application of CRM principles will usually be the road to successfully coping. LOFT details have become a standard component of most commercial operator aircraft type training. In addition to LOFT scenarios, it is even more important for simulator training to be used to address abnormal flight conditions, those which are not expected to be encountered in normal flight operations, such as aircraft upsets and stalls.

All flight crew members need to complete CRM training at various stages of their careers, including initial and recurrent training. It can be particularly critical, in conjunction with leadership training, when first officers upgrade to captain. Training must be carried out by approved instructors and must follow approved syllabi, which must be detailed in the manuals. The CRM training at Colgan had been essentially static and unchanged for ten years prior to the accident. It covered the same issues and accident/ events since Edward Yarid, Manager of Crewmember Training, started at Colgan in April 1999.[78] It did not keep pace with industry and academic studies of CRM, it did not incorporate advances in the areas discussed above and did not provide pilots with current, accurate information they needed to effectively manage the resources available to them.

2.3.5 Standardization

When there is a lack of adequate guidance on how to operate an aircraft, standardization suffers. Deficiencies in standardization occur as crew members begin to implement their own or passed on procedures, in lieu of firm guidance provided by complete and thorough manuals. The Colgan Q400 interim CFM was lacking adequate guidance on many areas of operation. Several examples of Colgan Q400 deficiencies are ice protection system guidance, bugging of appropriate approach and landing speeds, and training standards. Multiple interviews with Colgan check airmen revealed inconsistencies in the way SOPs were applied on the Q400, specifically in the bugging of approach and landings speeds flown as well as in the operation of the ice protection system. These variances can be attributed due to the absence of information put forth in the Q400 interim CFM. SOPs are not easily discernable in the interim CFM. There is a great deal of interpretation that is inferred in the text; unfortunately, in lieu of a proper document, the aircrews operating the aircraft had minimal guidance on the SOPs. The Manager of Flight Standards, Sheri Baxter, made repeated requests to attend Q400 training and become rated in the Q400. Her duties included being in charge of the check airman in the company and increasing flight standards amongst the pilot group.[79] She stated she was able to perform her job adequately; however, she also realized she was missing integral knowledge in the operation of the Q400 aircraft. Furthermore, she acknowledged that "all the pilots" were asking for a Q400 CFM that was equivalent to the Beech or the Saab.[80] She also mentioned the Flight Standards department requested a permanent CFM be finalized "many, many times."[81]

Guidance contained within the interim CFM regarding the proper operation of the ice protection system was lacking. As a result, the procedures Colgan pilots used to operate the ice protection system, both in flight and on the ground, varied from crew to crew. Several examples were noted during the Operations group interviews of pilots.[82,83] As per the Q400 AOM and AFM, the ice protection system is to be tested on the ground if flight into icing is expected. A review of the interim CFM shows this guidance has been omitted. However Check Airman Dittmar stated the ice protection test is always conducted in-flight.[84] Another aspect of the ice protection system operation discrepancy would be the guidance on when to activate the system to prevent ice accumulation on the airframe. Check Airmen interviews showed, that there was a mixture of personal techniques on system operation being communicated to flight crews.

[78] Operations Group Chairman Interview Summary – Manager, Crewmember and Dispatcher Training Edward Yarid
[79] Operations Group Chairman Interview Summary – Manager of Flight Standards Sheri Baxter, Page 6-7
[80] Operations Group Chairman Interview Summary – Manager of Flight Standards Sheri Baxter, Page 56
[81] Operations Group Chairman Interview Summary – Manager of Flight Standards Sheri Baxter, Page 56
[82] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 10-11
[83] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 9
[84] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 9

The same Check Airman stated he operates the ice protection system in the following manner. He turns the system on in the following order: boots, prop, windshield heat, and increased ref speed. He then stated there is no guidance on which switch comes first in the flow.[85] This is correct as a review of the interim CFM shows no guidance for operating the ice protection systems, just strictly limitations for operating in icing conditions. A review though of the Q400 QRH and AFM sections containing guidance for operations in icing conditions has a clear, defined procedure for turning on the ice protection, with the leading edge boots being turned on last.[86,87] It is important to recognize that this lack of standardization can effectively counter good CRM. If one pilot fails to perform a particular action, the other cannot recognize it as a deviation from SOP if he or she has seen every pilot perform the action differently. In the case of the "techniques" noted above, the variances ranged from which system to use, when to use them, and what call-outs to use when manipulating the switches.[88,89,90] This Check Airman again stated the engine display 'Ice Detected' alert was a failsafe to operate the ice protection system. The Aircraft Operating Manual (AOM) states the 'Ice Detected' message is an acceptable cue to initiate ice protection system activation. Another Check Airman described his ice protection activation in multiple steps, depending on the current conditions. Since the accident Colgan has adopted the use of ice protection "levels" to guide ice protection systems use.[91] At the time of the accident, the only CFM reference to operating in icing conditions referred to limitations for operating in icing conditions.[92]

Another example of a lack of standardization is in the operation of the ice protection system, there is a discrepancy on which crewmember actually manipulates the controls. In one section (Expanded Checklist) the manual states the captain should turn off the system as part of the captains' after landing flow; in another section (Cockpit Flows) turning off the ice protection is stated as being a part of the first officers' after landing flow.[93,94] Further illustrating the confusion, in an interview with a Colgan First Officer, he recounted that the accident Captain had asked him to turn off the pitot heat because he thought it was in the CFM, but not on the After Landing checklist.[95]

The interim CFM describes the standard approach and landing profiles; however, it was noted by several check airmen there are many techniques and individual procedures actually being used when airspeeds are bugged. In fact, per the interim CFM, V_{ref} and V_{ga} speeds are to be bugged prior conducting the Approach Checklist. During the various interviews, some check airman described their own technique for bugging speeds and for selecting speeds they actually flew on an approach. Those interviews revealed a lack of a standardized procedure to maintain or fly a specific speed. One Colgan Check

[85] Group Chairman's Factual- Operations Group, Page 11
[86] Operations Group Chairman Q400 QRH – Flight in Icing Conditions
[87] Operations Group chairman Q400 AFM – 4.7.2 Ice Protection Procedures
[88] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 10
[89] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 9-12, 49
[90] Operations Group Chairman Interview Summary – Q400 Check Airman Scott Moberly, Page 35-36, 57-58
[91] Operations Group Chairman Q400 CFM Operations Bulletin 09-001
[92] Group Chairman's Factual- Operations Group, Page 16
[93] Colgan Air, Inc. Q400 Interim CFM – Section Five, Page 31
[94] Colgan Air, Inc. Q400 Interim CFM – Section Six, Page 2
[95] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 45

Airman stated he bugged certain speeds above and below 10,000MSL; and that it was a personal technique, not company SOP.[96] In addition, two additional Colgan Check Airmen described their approach speed procedures to be contrary to SOP.[97,98] Another variation on the bugging approach speeds was described by a fourth Colgan Check Airman who bugs them approximately 20-30 minutes prior to arrival.[99] These variations and deviations from SOP as routinely practiced by company Check Airmen illustrate that there was no real procedure being followed, or taught, on when to bug these speeds.

Colgan themselves acknowledged in the February 2009 flight standards monthly newsletter that they needed to improve overall line standardization: "2009 will be a year for catching our breath after the immense growth from 2008 to build a better infrastructure in the standards department, increase standards within the pilot group, issue new CFM's for the Saab and the Q400, adopt the new procedures, and establish a stronger flight standards presence in our flight operations."[100]

2.3.6 Pilot Bases and Commuting

The accident Captain and First Officer both commuted to work. Commuting, in aviation terms means they did not live where they were based in Newark, NJ; rather, they traveled to their base, typically by jumpseating, often on other air carriers.[101] Commuting in some instances may be a lifestyle choice by some pilots for personal reasons. This was not the case for the accident crew. Commuting is a reality of the industry, frequently the result of low pay, especially at the regional airline level, high cost of living in many airline bases and frequent changes of base assignment as a function of the airline's business practices. In fact, many pilots have no choice but to live elsewhere and commute to their assigned base for this reason. Locality cost-of-living overrides are provided to Colgan management personnel; however pilots do not receive this compensation.[102]

In some cases regional airlines have formed agreements with multiple mainline carriers to secure additional flying. Colgan did this when they became both a Continental Connection and United Express carrier in 2005. Previously, they had only operated as a US Airways Express contractor. Eventually, in 2008, Colgan took delivery of the Q-400 type aircraft and began operating them for Continental Airlines with bases in Albany, NY; Baltimore, MD; Newark, NJ; Norfolk, VA; and Pittsburgh, PA. In less than two years, the only Q-400 base that remains open is Newark, NJ. Mainline carriers change route structure for regional feeders regularly; this practice forces the regional partner into base restructuring. Opening and closing bases is a routine practice for Colgan. In fact, in the past two years, over 20 bases have closed (**Appendix A: Colgan Pilot Base Closures**); although, during the public hearing it was stated only 10

[96] Operations Group Chairman Interview Summary – Q400 Check Airman Scott Moberly, Page 58-60
[97] Operations Group Chairman Interview Summary – Q400 Aircrew Program Designee Sam Omair, Page 68-69
[98] Operations Group Chairman Interview Summary – Q400 Check Airman Dean Nitsos, Page 12
[99] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 14
[100] Human Performance Group Chairman Factual Report Attachment 2: Monthly Flight Standards Newsletter Information
[101] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 3
[102] Colgan Air, Inc. Public Hearing Day 2, Page 352

bases have closed in this time period.[103] One Colgan Check Airman, who has been employed as a pilot with Colgan for nearly five years, has been transferred to different bases four times.[104] This frequency of bases opening and closing creates a great deal of additional strain on the aircrews. Colgan provides little time off to search for, obtain housing, and move to the pilot's new domicile. Therefore, a pilot has little opportunity to secure new living arrangements and complete a move, all the while maintaining a full work schedule.

Another reason for pilots to commute is the high cost of living in the major metropolitan cities, in this case the New York-Newark area. One Colgan First Officer said that he estimated 75-80% of the pilots at Newark commute due to the high cost of living in the area and low wages.[105] Anecdotal evidence suggests typical commuter housing costs in Newark average $250 per month. This means, First Officer Shaw would have spent approximately 20% of her gross salary ($3000 per year), in addition to the housing costs at her primary residence, for the benefit of working in Newark. That, coupled with the already alarmingly low salary gave her few options but to live with her parents and complete a transcontinental commute.

Due to challenging schedules, pilots who commute regularly give up days off to travel to their base. When a pilot commutes at least one day per week and often more is spent commuting to or from work, meaning the pilot has minimal time at home. While 10-12 days off might sound like plenty of time, in fact, a commuting pilot will use anywhere from 4 to 8 of those days travelling to/ from work. So, in the end, a pilot will only have a few days per month to actually spend at home as time off and away from work. A Colgan First Officer stated there is never enough time at home.[106]

Pilots employed by Colgan were faced with another problem related to commuting. At Colgan, first officers were not able to choose their base prior to accepting an upgrade to captain. So, they were faced with making a choice whether to accept the upgrade and the pay raise associated with becoming a captain or remain a first officer, while accepting the fact that they may be transferred to another base at the completion of training. The other option would be to turn down an upgrade and remain in a base for quality-of-life reasons such as not having to commute but continue on the first officer salary.

2.3.7 Company Safety Culture

Safety culture is the product of individual and group values, attitudes, competencies, and patterns of behavior that determine the commitment to, and the style and proficiency of, the organization's management of safety. An important aspect to developing an effective safety culture, which will promote and encourage a robust safety culture is *mutual trust* (Federal Aviation Administration, 2006). Employees must feel that safety is not just a moniker that management is required to say, but that upper level management truly desires safety first. This can be accomplished by management putting

[103] Colgan Air, Inc. Public Hearing Day 2, Page 339
[104] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 11
[105] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 29
[106] Operations Group Chairman Interview Summaries during Field Investigation – Buffalo, Page 2

words into action so that "Safety Is Our #1 Priority" can be truly seen from the highest levels of management, which will then be translated to the entire workforce.

Colgan management consistently stated that "Safety Is Our #1 Priority," but their actions demonstrated that reliability and on-time performance were the true drivers. The July 2008 Flight Standards newsletter said that "Performance is foremost on the minds of the Flight Ops Department."[107] Safety practices at Colgan were not proactively implemented as a means to improve the overall operation. Information disseminated to pilots on a regular basis frequently concluded with harsh, threatening statements with disciplinary undertones, alluding to the possibility of termination, letters in employee files, and possible FAA actions.

One such example relates to gate returns. Colgan had experienced several aircraft returning to the gate to correct a maintenance discrepancy ("write-up") when flight crews inadvertently placed switches in the incorrect position. In Read & Sign 08-16, Regional Chief Pilot Billy Morency addressed the issue:

> PILOT INDUCED ERRORS
>
> Recently we have had some gate returns and maintenance write ups due to pilots not having the switches in the correct position or not doing proper scans. It is absolutely imperative that we be diligent in our duties and ensures that the cause for the malfunction is not pilot induced. If it is found to be pilot error for causing gate returns or delays, the pilot will be subject to retraining and a correct letter in their file.[108]

Note the use of the phrase "subject to" when applied to training. This clearly indicates that training was being used as a threat, not a tool for improving the operation. Instead of investigating the issue and seeing if there is a procedural issue that can be addressed to rectify the problem, the Regional Chief Pilot attempts correction through disciplinary action.

Demonstrations of this unjust corporate culture were evident from even higher in Colgan management, Director of Operations, Dean Bandavanis put out Read & Sign 08-08:

> **<u>Effective immediately</u>** Colgan Air Flight Standards personnel, Chief Pilot, Regional Chief Pilots, Q400 and SF-340 Program Managers, Designated Examiners and Check Airmen are going to be occupying the jump seat to verify compliance with all speed limitations. Any operations above **<u>Vmo -10</u>** will be reported to Flight Standards for *appropriate action*. [Emphasis added]

Read & Signs were not only used to communicate operational information, but also company policies. Heavy handed enforcement further undermined their safety culture.

> Read & Sign 08-13 "If a Crew Member is based in EWR than (sic) you are responsible for your own overnight accommodations. Sleeping in Operations or any crew room in EWR is strictly

[107] Human Performance Group Chairman Factual Report Attachment 2: Monthly Flight Standards Newsletter Information

[108] HP Group Chairman Factual Report Attachment 4: Read and Sign Memo Information, Page 5

> prohibited and will have severe disciplinary consequences, *up to and including termination*." [Emphasis Added]

This enforcement mentality leads to a non-reporting culture. This is clearly demonstrated in the safety reports generated by both the anonymous 1-800 safety hotline, as well as the Colgan version of their ASAP program. When asked how many calls have ever been received by that phone number, the Colgan Director of Safety, Daryl LaClair, said *"[w]e haven't had any."*[109] The Director of Safety says that he does not see an issue with that and that he feels Colgan's safety culture is very good. Again demonstrating a reactive culture, Mr. LaClair says that he feels that the safety culture is very good "[b]ecause we have very limited occurrences of any type, injuries or you know, it's -- we're out there, I mean, and they know we're out there."[110] When the Director of Safety infers that the workforce is compliant because "they know we're out there," it obviously demonstrates a punitive work environment. With regards to the ASAP program, Mr. Morgan, the Vice-President of Flight Safety and Regulatory Compliance, states that they typically receive 12 to 15 reports per month, on average.[111] While reporting figures for other carriers ASAP programs are not typically published, ALPA's experiences with ASAP programs says this number of reports is very low, for the relative scale of Colgan's operation.

Another key indicator of management's ideology towards safety is in its sick and fatigue policies. Mary Finnigan outlined Colgan's sick policy during her Public Hearing testimony and stated that the same policy is applicable to everyone in the company. The inconsistency is that Colgan's policy does not address the inherent differences between employee groups. Office employees are able to work sick (i.e. cold, sinus infection) or after an accident or surgery (i.e. on crutches or in a cast). Pilots and flight attendants, on the other hand, are not able to work with those types of illnesses or conditions. As a result, they would routinely have to call in sick more often than office employees. Colgan's method of paying pilots for sick leave also discourages pilots to call in sick. Pilots do not accrue sick leave for the first 90 days of employment, so any sick calls during that time a pilot would not be paid for their trip.[112] Secondly, Colgan pilots only accrue a half a day of sick leave per month. As a general rule, a pilot who is sick for the beginning of a trip would have to drop the entire trip. Therefore, for a pilot to accrue enough sick leave for a four day trip, a pilot would have to be employed for eleven months. When a pilot calls in sick for a trip, they are not compensated for the flight hours they missed, but are instead paid a flat credit of three-hours-and-forty-five minutes per day. This is usually less hours than most trips are worth. These policies were illustrated by comments made on the CVR by the accident First Officer, who said that if she called in sick, she would have had to get a hotel [at her own uncompensated expense] until she felt better.[113]

[109] Operations Group Chairman Interview Summary – Director of Safety Daryl LaClair, Page 12
[110] Operations Group Chairman Interview Summary – Director of Safety Daryl LaClair, Page 28
[111] Colgan Air, Inc. Public Hearing Day 2, Page 395
[112] Colgan Air, Inc. Public Hearing Day 2, Page 373
[113] Cockpit Voice Recorder Group Chairman Factual Report Addendum, Page 12-25

Colgan's fatigue policy similarly discourages pilots from calling in fatigued. If a pilot is over their guarantee, then they would not be paid for a trip which they called in fatigued.[114] If a pilot called in fatigued, they would have to make two phone calls, one to dispatch and the other to the Operations Duty Officer. Then within 24 hours the pilot would also have to fill out a crew member fatigue form and deliver it to the Chief Pilot or Operations Duty Officer.

In looking at the safety culture of an airline, one would be remiss in failing to discuss their safety programs. As previously mentioned above, Colgan had an ineffective ASAP program. Management also said that their LOSA program was "not a full-blown program."[115]

An ASAP program is used to obtain voluntary safety reports from front-line employees, in this case pilots, to identify safety deficiencies in an organization and then implement corrective actions. Colgan believes that the ASAP program is only to be used when a pilot violates a company policy or FAR.[116] This lack of understanding of the program by upper level management at Colgan, along with the lack of trust by the front line employees, is arguably the reason that Colgan's ASAP reporting is so low.

Colgan had implemented a pseudo-LOSA program prior to the accident and had completed LOSA observations roughly one year prior the accident. A LOSA program is built upon experts and highly trained observers monitoring operations from the jumpseat and obtaining safety-related data on environmental conditions, operational complexities, and fight crew performance (Federal Aviation Administration, 2006). The key component is that LOSA is non-jeopardy and confidential. During their first set of LOSA observations, Colgan recruited check airmen to ride along in the jumpseat and collect the LOSA data. These would be the same check airmen that would be giving crews line checks, proficiency checks, and special emphasis audits all of which were jeopardy events. Conducting LOSA in this manner sets the program up for failure. Even the Vice-President of Safety and Regulatory Affairs said that the program was not administered appropriately.[117]

Another safety program, FOQA was in the process of being implemented at Colgan, but as the FAA POI stated it was "a bit hung up."[118] On a scale of 1-10, 1 being at the beginning and 10 having an up and running program, the FAA POI said they were at a 1.[119] FOQA allows an airline to collect objective, parametric data from appropriately equipped aircraft (e.g. speeds, control settings, altitudes, etc). Such data is then compiled and, on an aggregate basis, used to identify safety trends and develop corrective actions. Incorporating FOQA into the airline will provide critical information that previously was not available. The concern will be its implementation, as we have seen in the previous two programs, ASAP and LOSA, improper implementation can lead to an ineffective program.

[114] Colgan Air, Inc. Public Hearing Day 2, Page 332-333
[115] Colgan Air, Inc. Public Hearing Day 2, Page 418
[116] Operations Group Chairman Interview Summary – Director of Safety Daryl LaClair, Page 13
[117] Colgan Air, Inc. Public Hearing Day 2, Page 459
[118] Colgan Air, Inc. Public Hearing Day 2, Page 480
[119] Colgan Air, Inc. Public Hearing Day 2, Page 480-481

Although Colgan management talked a lot about Safety Management Systems (SMS) during their interviews and Public Hearing testimony; it is evident that a Safety Management Systems did not exist at Colgan. SMS must be ingrained from the highest level of management and is more than a program- it's a commitment to safety that permeates throughout the organization. It is a quality management approach to controlling risk, but in order to be effective, the organization must develop a just culture. This will enhance and complement a key required piece of an SMS program- a robust reporting culture.

2.4 Human Factors

2.4.1 Crew Resource Management

CRM is more subject to breakdowns at night and/or IMC because of adverse physiological (ex spatial disorientation) and mental states (ex. fatigue). "When visual cues are limited, aircrew coordination, both internal and external to the cockpit, is even more critical than usual" (Shappell & Wiegmann, 2003, p. 139). A lack of appropriate CRM training and skill sets can be traced to inadequacies in organizational processes and human resources management. In CRM training, crews should be taught techniques for managing workload that can help with concurrent task management, for example those concurrent aviation, navigation, communication, procedural, systems operation, monitoring, challenge and decision tasks found during the approach to landing phase of flight. Systems should be designed and tasks distributed to ensure that no one person is disproportionately overloaded (Dismukes, Loukopolous, & Barshi, 2009, p. 124). When they are not, this confluence of concurrent task demands and inadequate defensive barriers can exponentially increase vulnerability to error, especially errors of omission. In the flow of continuous, interleaved tasks in this accident, the critical omission was the airspeed scan, exacerbated by fatigue. The inadequate defensive barrier in this accident was the lack of a low airspeed alerting or protection system.

Four prototypical situations appear when errors of omission are present: 1) interruptions and distractions, 2) tasks that cannot be executed in the normal, practiced sequence of procedures, 3) unanticipated new tasks that arise and 4) multiple tasks that interleave (Dismukes, Loukopolous, & Barshi, 2009, p. 80). In this accident there were distractions of short vectors to the final approach, icing conditions, instrument meteorological conditions, and timing of ATC communications. Interruption of aircraft configuration for checklists and communication tasks led to inattention to airspeed, and the unanticipated new tasks of recognizing and recovering from an unexpected autopilot disconnect and nose high attitude, put the crew deep into an extreme condition. Another factor in this accident is that the second pilot did not catch the first pilot's error, which can be viewed as systems vulnerability. The flying pilot intended to monitor airspeed and advance the throttles as had been done many previous times, but one or more of the four prototypical situations disrupted the cognitive prospective memory to return to that task. Often times the interruption is so prominent, for example the illumination of the icing indication or a radio call, that "the individuals may not have time to encode an intention to resume, or even think to do so, much less create conspicuous cues to do so to serve as reminders" (Dismukes, Loukopolous, & Barshi, 2009, p. 88). In this accident, the low airspeed cue was not a prominent or timely reminder to monitor and adjust power. This indicates inadequate systems and task timing design.

The cognitive process involved with concurrent task management also relies heavily on habits, and automatic processing relies on context or clues. The pilot flying may have had an internal clock disrupted by the activation of shaker at the higher ref speeds, and this requires the remaining amounts of cognitive reserve to go towards not just determining current aircraft state, but to manage and switch among the continual stream of other tasks. Placed in this situation of attention switching, pilots become vulnerable to source memory confusion and often reenter the stream and try to complete the wrong task. This could contribute to the explanation of why the pilot flying initially raised the nose of the aircraft when already nose high, and why the copilot raised the flaps without directive.

2.4.2 Spatial Disorientation

Somatogravic illusion must be considered as a factor during initial perception of undesired aircraft state and decision formation, because of the conditions that existed and the flight path of the aircraft. This has been studied exclusively and is known to cause the characteristic flight path exhibited by the accident aircraft. FDR data reveals rapid deceleration and that the pilot initially pulled back on the controls, increasing the angle of attack. The CVR is inconclusive, except absence of callouts for stall recovery may be supporting indicators. It is probable that the pilot flying initially did not perceive a stall but rather excessive pitch down due to deceleration resulting from power reduction, gear deployment, propeller drag increase, induced drag from increased angle of attack and parasitic drag from flap deployment. The aircraft decelerated 50 knots in 26 seconds, which would produce a strong deceleration force and vestibular illusion of tumbling forward.

The FAA's Aeronautical Information Manual has a section on Illusions Leading to Spatial Disorientation. The section, in part, stated: “Various complex motions and forces and certain visual scenes encountered in flight can create illusions of motion and position...(d) Somatogravic illusion. A rapid acceleration during takeoff can create the illusion of being in a nose up attitude. The disoriented pilot will push the aircraft into a nose low, or dive attitude. A rapid deceleration by a quick reduction of the throttles can have the opposite effect, with the disoriented pilot pulling the aircraft into a nose up, or stall attitude” (Federal Aviation Administration, 2009, pp. 8-1-5.b.2.d).

> “DR. DISMUKES: Well, it can take a long time. In this case, I don't see any evidence that he ever understood the situation he was in. I mean he knew something was wrong, but I don't know if he ever finally said, wait a minute. I've got to get the nose down no matter where I am. I've got to get the nose down. He did advance the throttles but -- I haven't seen the FDR data but I don't know if he ever did what he had to do at that point which is get the nose down to recover flying speed, reduce the angle of attack."[120]

This illusion has been cited seven times by the NTSB in the last 10 years, and was recently cited in a factual report where the cause of the accident was listed as “the pilot's spatial disorientation…”, which “…resulted in a loss of control and subsequent collision with trees” (National Transportation Safety Board, 2009). Somatogravic illusion was also cited as a factor in NTSB accident reports DEN04FA104, CHI08FA066, NYC08LA223, NYC03FA205, LAX03FA254, NYC01FA214 and most recently by the Transportation Safety Board of Canada as part of their accident investigation of a multi-engine propeller airplane crash (Transportation Safety Board of Canada, 2007).

> “The somatogravic illusion occurs in conditions of poor visibility or in darkness when there is an absence of visual cues. Instrument-rated and experienced pilots are not immune to this illusion, which is a subtle and dangerous form of disorientation. The illusion occurs because the body relies on sensory organs in the inner ear to maintain balance and, in the absence of visual cues,

[120] Colgan Air, Inc. Public Hearing Day 3, Page 606

> signals from these organs can produce a very powerful disorientation. In the case of an aircraft that is accelerating during a go-around, the sense organs of the inner ear of the pilot send a signal to the pilot's brain that is interpreted as tilting backwards instead of accelerating forward.
>
> According to text in the *Fundamentals of Aerospace Medicine*, "A relatively slow aircraft, accelerating from 100 to 130 knots over a 10-second period just after take-off, generates +0.16 Gx on the pilot. Although the resultant gravitoinertial force is only 1.01 G, barely more than the perceptible force of gravity, it is directed 9° aft signifying to the unwary pilot a 9° nose-up pitch attitude (Davis 2008, 171). If the aircraft nose is simultaneously raised, which is usually the case in a go-around, the pilot has a very strong sensation of climbing. The illusion of false climb tends to lead the pilot to lower the nose and descend. The aircraft then accelerates and the illusion can intensify. If the aircraft is being flown in proximity to the ground, ground contact can occur before the pilot can assimilate information from the aircraft's instruments, overcome the powerful illusion, and take corrective action" (Transportation Safety Board of Canada, 2007).

According to the FAA Airplane Flying Handbook (FAA-H-8083-3), "Night flying is very different from day flying and demands more attention of the pilot. The most noticeable difference is the limited availability of outside visual references. Therefore, flight instruments should be used to a greater degree." Generally, at night it is difficult to see clouds and restrictions to visibility, particularly on dark nights or under overcast. "The vestibular sense (motion sensing by the inner ear) in particular tends to confuse the pilot. Because of inertia, the sensory areas of the inner ear cannot detect slight changes in the attitude of the airplane, nor can they accurately sense attitude changes that occur at a uniform rate over a period of time. On the other hand, false sensations are often generated; leading the pilot to believe the attitude of the airplane has changed when in fact, it has not. These false sensations result in the pilot experiencing spatial disorientation."

Spatial disorientation has been cited by NTSB in accident and incident reports 200 times since January 1, 1999. In one event, a commercial airliner climbing out over the water rolled over 60 degrees to the right before the pilot flying realized the upset condition. In this incident the NTSB determined the probable cause to be linked to spatial disorientation. Other factors in the incident were the cloud layer and dark night. The NTSB also referenced Federal Aviation Administration Advisory Circular (AC) 60-4A, "Pilot's Spatial Disorientation," where upset recovery tests were conducted with qualified instrument pilots. "The results indicated that it can take as long as 35 seconds to establish full control by instruments after a loss of visual reference of the earth's surface. AC 60-4A further stated that surface references and the natural horizon may become obscured even though visibility may be above visual flight rules minimums and that an inability to perceive the natural horizon or surface references is common during flights over water, at night, in sparsely populated areas, and in low-visibility conditions" (National Transportation safety Board, 2001).

In another event, a commercial airliner slowed below stall speed after the autothrottles disconnected for an undetermined reason (National Transportation Safety Board, 1997). The aircraft subsequently lost 3,000 feet before the pilots could recover. The germane point here is the amount of time and altitude required to recognize the effects of spatial disorientation, then recognize and recover from the upset and subsequent stall is significant.

2.4.3 Electronic Display on Flight Instrumentation

A display is the primary means of presenting information to the flight crew's visual and aural senses. Displays should alert the crew and draw attention, represent the nature of the condition and when possible recommend or direct corrective actions. The low airspeed cue simply provides information in a passive fashion, not clearly and unambiguously indicative of an impending upset or out of control flight situation. This design is a tradeoff accepted during transition to electronic flight instrument systems (EFIS) and primary flight display (PFD), and this mishap identifies an emerging hazard. EFIS and the PFD is supposed to reduce the risks of visual illusions and spatial disorientation during instrument flight conditions by supplementing normal visual cues, but the tape system currently used is not intuitive. There is very little positional movement of the display due to the nature of the design, unlike a conventional analog airspeed indicator where experienced pilots can build appropriate mental models of airspeed based on position of the airspeed needle alone. The PFD airspeed tape appears static during the conventional instrument scan, and movement is not noticed unless focused attention is placed on the display, which is not a good information retrieval strategy when managing concurrent tasks during periods of high workload. Compounding this problem is the fact that the airspeed tape and altitude tape represent information in a radically different manner. If the airspeed tape is rising, airspeed is decreasing and a correction could require pitch down. Conversely, if the altitude tape is rising, the aircraft is descending and a correction would require pitch up. While this may be satisfactory to a pilot placed in an automation monitoring role, it is not intuitive to a pilot with who has predominant experience with conventional instrument displays and thus has that "embedded " in his or her mental model of the instrument scan.

The characteristics of a good cue are: It should attract attention at the critical time (conspicuous), it should have sufficient information about what task needs to be carried out (content) and when (context), and it should allow the operator to ensure correct performance of the task (Reason, 1997, p. 98). The accident pilot's scan was developed on conventional flight instruments, round dial aircraft. Salient cues for airspeed are presented and learned differently in this environment, and imprint onto cognitive memory. A transition to electronic flight instrument systems is challenging, and needed research is ongoing in this area. Tape displays may be adaptable to the operational environment, but current low airspeed cues and lack of alerts, caution warnings and safeguards are to be considered hazards, especially in reduced visual conditions.

2.5 FAA Oversight

2.5.1 FAA Structure

The FAA is required to provide oversight that ensures airlines meet their statutory duty to provide service with the highest possible level of safety in the public interest. This is done primarily by providing information, recommendations, advice developing current, pertinent regulations and enforcing those regulations.

Regulations provide the only true compulsory level of compliance, but as was clearly noted during the Public Hearing, compliance with regulations alone does not provide the highest level of safety.

> "Regulations contain the minimal standards. They're the floor. Carriers and operators and pilots, everybody, can go above that but that's the minimum…"[121]

Issuing or modifying Federal Aviation Regulations (FARs) is complex process. It can require gathering facts, analysis, forming industry committees, and formulating wording that is then placed in the docket for comment. Captain Rick Clarke, the Manager of the FAA's Air Carrier Operations Branch, stated,

> "but it takes time to do a regulation. We've already seen there's been several different attempts of updating it. The actual Administrative Procedures Act is years long to produce a regulation."[122]

A regulation can meet stiff resistance from stakeholder groups who feel they would be adversely impacted and although it may be sound and provide clear safety improvement, it may still not be implemented. This means that much change and improvement created by the FAA in the airline industry comes through non-compulsory methods. These methods include publishing information on best practices, guidance and recommendations on suggested programs and improvements for distribution to airlines, using FAA management offices to provide guidance, and approval and acceptance of certain manuals or procedures. While these have a role, the regulated party is under no obligation to comply and may implement its own programs, processes, etc that are contradictory to the FAA guidance, provided they are not in clear violation of the regulations.

Regulation and informational materials for airlines and management of Certificate Management Offices (CMO) that work directly with the airline is handled primarily by Branches or Divisions that are responsible for specific areas of aviation operations. A branch may perform these duties that provide general guidance, but do not usually get involved directly with the management of a particular airline certificate. This is done through local Certificate Management Offices that are part of a Regional Division which in turns reports to a specific Branch of the FAA.

The FAA provides oversight primarily on a local level through a Certificate Management Office. This office will include a Principle Operations Inspector (POI), as well as other inspectors as necessary that assist in oversight and answer to the POI. One of the POI's main duties is to ensure that all applicable

[121] Colgan Air, Inc. Public Hearing Day 3, Page 720
[122] Colgan Air, Inc. Public Hearing Day 3, Page 719-720

FARs are complied with by the airline. The POI's oversight duties also include, but are not limited to, training of pilots, approval of required manuals, and operational policies that the airline may need to adopt.

2.5.2 Compliance

An airline must have certain executives, with explicitly defined positions in the organization, who have responsibilities that are outlined and required by the FARs. The POI must work with these individuals to ensure that the airline is in compliance with the FARs and meets the intent of providing "the highest possible degree of safety." Ensuring FAR compliance is relatively straightforward. However, making sure that the airline is managed, training is provided, and aircraft are flown in a responsible manner that meets the level of safety described above is a different matter. Although the stated goals of "highest level of safety" may be identical between the two entities (the airline and the FAA), interpretations of the method and measure of their achievement must certainly conflict. Enormous pressures of containing expenditures affect every decision considered by an airline. On time reporting, passenger convenience, marketing needs, and many other concerns further influence decisions that affect operations. Opinions on risk assessment and potential reward may vary both within an airline and between the airline and the FAA.

The POI and the CMO have few options to force an airline to meet their particular designs of best operating procedures or policies. Although delaying approval of programs or manuals considered substandard for example, can be an effective means of persuasion for a CMO, it may also place them in a showdown with the airline if the airline's position is that compliance with more than the minimum *required* standard might result in significant financial harm. This can be especially significant to regional airlines that may have limited financial reserves. These airlines often bid on block flying times to provide service for major airlines. This bidding may often result in small profit margins that may be unrecoverable if costs climb. Further, financial penalties and contract cancellations are often imposed by the "mainline" carrier on regional airlines that do not meet specific goals for on time performance, flight completion, and other performance measures. This means in many cases, compromise is necessary. Often this may have no significant effect on safety, as other means of compliance are satisfactory. However, CMOs do encounter conflicts or frustrations that may never be fully resolved to their satisfaction. This negotiation is illustrated in a comment by the Colgan POI about a previous Colgan Director of Operations.

> "I'd say it was a bit more challenging than I was used to. I needed to a little more persuasion with him. But, ultimately, he was a very knowledgeable person and we did get the compliance results we were looking for."[123]

Thus in many instances, the primary method of producing change used by the FAA is persuasion. This is not a very powerful tool. FAA Inspectors comments in this investigation reflected some frustration.

> "I think the POI's main tools are diplomatic persuasion, arm twisting…"[124]

[123] Colgan Air, Inc. Public Hearing Day 2, Page 473

As noted elsewhere in this analysis, the primary manual used by Colgan pilots to operate their aircraft is the Company Flight Manual.

> "… the Company Flight Manual is a way of integrating the Colgan-specific -- company-specific procedures as far as normal procedures, emergency procedures, performance and limitations, and also potentially systems information, and put it into one convenient book."[125]

The Q400 was placed on-line with what has been described by the FAA and Colgan management as an "***interim"*** Company Flight Manual. It earned this descriptor because it was recognized as being sufficiently different in structure from established company flight manuals in format and content. This included whole sections of procedures, systems descriptions, training materials and other content and procedures needed to safely guide the Colgan pilot in operation of the Q 400 which were not included in the CFM.

The decision to place the Q400 in service without an adequate Company Flight Manual appeared to be driven by forces outside the concern of management or control of the FAA.

> "I think the POI's main tools are diplomatic persuasion, arm twisting, but ultimately, the companies' manuals come on their own schedule. When changes came that we felt needed to be addressed, we would put them out in bulletins rather than waiting for the ultimate final version of the Company Flight Manual."[126]

Once the Q 400 was allowed to operate on-line without a finished CFM, pressure and interest in the completion of the Q400 CFM waned. A "hiatus" ensued and did not ebb until the accident happened. Doug Lundgren, the FAA POI for Colgan, stated,

> "The company started to work on the three-ring binder… final version, back in August… we handed the final version back to them just before Christmas then the company took a hiatus from the development… Then the accident happened and March 1st they restarted work on the manual…"[127]

2.5.3 Feedback

The basic structure of the FAA compliance pyramid is that rulemaking, guidance and information distribution is generated at the top. Responsibility for enforcement of regulation and enactment of guidance is at the bottom. One result of this is that the persons with the least political capital, the inspectors, are charged with most difficult task of cajoling the airlines to comply. This is illustrated in a response from the Manager of Air Carrier Operations, Air Transportation Division of the FAA:

> CAPT. COX: If safety issues arise at a particular carrier, do you have any input as to some of the oversight issues or methods or inspection type of activities that might want to take place?

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[124] Colgan Air, Inc. Public Hearing Day 2, Page 479
[125] Colgan Air, Inc. Public Hearing Day 2, Page 495
[126] Colgan Air, Inc. Public Hearing Day 2, Page 479
[127] Colgan Air, Inc. Public Hearing Day 2, Page 495-496

CAPT. CLARKE: We can provide advice. … the principle always being try to deal with things at the lowest level.[128]

This separation demands that most of these struggles take place out of sight of the Divisions or Branch levels of the FAA. FAA headquarters may receive little feedback on the actual condition of the various cultures of compliance with best practices at the airline level.

CAPT. COX: Would the principal operations inspectors working at air carriers have a reporting relationship to you?

CAPT. CLARKE: No, sir, they don't. They would report to their certificate office and then up to the regions. We work with them. We provide guidance to them. We provide advise [sic] to them, but they don't report to us.[129]

A real lack of the flow of critical information upward to the National Branch level and meaningful support downward to the local Certificate Management Office appears to exist. A specific example is the development and issuance of Safety Alerts for Operators (SAFOs) from the Branch level to the airlines.

A SAFO contains important safety information and may include recommended action. SAFO content should be especially valuable to air carriers in meeting their statutory duty to provide service with the highest possible degree of safety in the public interest.[130]

SAFOs are produced at the Branch Level and posted on a web site. A notice describing the SAFO is sent to Operations Inspectors and then they are the only ones who then determine if it applies to the carriers they oversee. The inspectors are in turn required to notify the airline. The POI is specifically not responsible for seeing that the information and recommendations in the SAFOs are acted on. This is defined the FAA Order establishing the SAFO program:

b. Significantly, SAFOs do not burden FAA inspectors with additional responsibilities not included in their work programs and not processed in accordance with the agreement between the FAA and its inspectors' bargaining unit. The responsibility to implement any action recommended in a SAFO rests with the operator.[131]

c. We encourage FAA inspectors to become familiar with SAFOs in general. Each inspector should pay particular attention to any SAFO applying directly to the operator(s) that he or she oversees. (FAA Order 8000.87A)

Part C. above implies the inspector has some responsibility in the SAFO as it applies to the operator, yet it ends at "familiarity" and "attention". The POI from Colgan expressed some frustration with this situation when asked if he is required to take a SAFO and pass it on to the airline:

[128] Colgan Air, Inc. Public Hearing Day 3, Page 693-694
[129] Colgan Air, Inc. Public Hearing Day 3, Page 691-692
[130] Human Performance Exhibit 14J: FAA Order 8000.87A Dated 10/24/06 Safety Alerts for Operators
[131] Human Performance Exhibit 14J: FAA Order 8000.87A Dated 10/24/06 Safety Alerts for Operators

> "Actually, not. Our requirement right now is we have to pass notices to the company. Now, I do -- I, as an individual, pass SAFOs on to the company. But I would like there to be accountability for SAFOs, as well. I would like a formal response from the carrier as to whether this applies or doesn't apply and if it does apply, what are they going to do about it and when."[132]

The POI is not tasked with following up on the status of SAFOs that apply to their carriers and no other mechanism exists. This leaves the FAA ignorant from the CMO to the very top of the FAA structure of the actual enactment of a crucial part of their oversight system.

> "We haven't followed up on the SAFO. The SAFO puts the information out. We don't have a system to follow up. I guess you would call it a feedback. It's been under consideration but we don't have that mechanism in place right now. That would be a special emphasis type of effort."[133]

This failure to obtain sufficient feedback leaves both the POI and the Branches unable to accurately calculate an individual airlines incorporation of safety information, recommendations, and techniques that are contained in SAFOs. This structure of filtered information and limited authority also create an atmosphere of plausible deniability. No one has the real power to change things outside of enforcing or creating regulation, therefore no one is responsible. There is no process to measure enactments of SAFOs, nor is any comprehensive feedback on airlines establishment of safety initiatives supplied back up the chain to the Branch. Therefore, the Branches or Divisions have little responsibility in tracking or measuring major indicators of a companies' safety culture. Nor can they provide any meaningful standard to allow a CMO to measure where their carrier "ranks" in comparison to others. The POI states that he uses conferences with other operators and PIOs to gather and share information.

The only outside opportunity for a reasonably objective evaluation of the hazards that were facing this airline before the accident belonged to the FAA. They had both the opportunity and obligation to step in and provide help, guidance, and action up to and including delaying the Q400 operation. Meaningful oversight and intervention did not materialize. The fact that it did not happen has more to do with the structure of enforcement and oversight at the FAA than it does with the failure of any one individual or department.

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[132] Operations Group Chairman Interview Summary – FAA Principal Operations Inspector Douglas Lundgren, Page 32

[133] Colgan Air, Inc. Public Hearing Day 3, Page 705

3.0 Conclusions

In the face of a broad spectrum of system failures and weaknesses, it is not possible to assign responsibility for an accident on a single factor. The immediate focus in most accidents is always on the last persons who nominally had the opportunity to prevent it, normally the flight crew. This tendency can be exacerbated if there are failures or other difficulty in an accident pilot's training background. The Captain had failed certain checkrides in his history as a pilot, as pilots have on many occasions. However, with additional training, he was able to retake and pass those checkrides, meeting FAA standards. The amount of training needed for a pilot to accomplish certain maneuvers varies from person to person. At the time of the accident, both crewmembers had received the FAA required training and passed the checkrides required for their positions. This investigation shows, unfortunately in hindsight, that the fundamental training this crew needed for the situation faced the night of the accident was inadequate. Further, all airline pilots are not required to get this training.

Early airplane training included recovery from full aerodynamic stalls, and most pilots have been exposed to that training very early in their flying experience. As high performance aircraft, many with swept wings, began to dominate fleets, the airline industry, including the FAA, recognized a full aerodynamic stall as a hazard to be avoided at all costs. Training was modified from recognition and recovery from full stalls to learning to identify the signs of impending stall and take action to avoid the full stall altogether, ostensibly creating a safer operation. This maneuver was termed "approach to stall". It was predicated on recovery at the first indication of an impending stall. This would prevent stalls so pilots would no longer need training in this flight regime. The recovery procedure for approach to stall recovery is substantially different from full stall recovery. The full stall recovery begins with the airplane no longer capable of sustained level flight and requires moving the control column forward to reduce the angle of attack. This reduced angle of attack breaks the stall and returns the aircraft to fully controlled flight. The approach to stall recovery maneuver is accomplished while the airplane is still fully controllable and normally is done with an objective of minimum altitude loss. This requires adding significant amounts of thrust and simultaneously moving the control column to control altitude, usually back. If the approach to stall recovery procedure was used during a full stall, a recovery might not be possible. The accident crew received no training in a full stall recovery, nor was it required by regulation.

This crew was trained on icing considerations by being shown a NASA produced video on aircraft icing. A portion of this video details the dangers of icing as it affects the control surfaces of aircraft. The danger highlighted is a tailplane stall. A tailplane stall can occur when ice forms on the leading edge of the horizontal tail surface, which disrupts the airflow and the tailplane stalls. This usually occurs when the airflow is modified by flap extension. This results in a violent pitch down motion which must be countered with immediate aft control column movement and immediate flap retraction. If these control movements were used during a full stall, they would aggravate the stall and likely make recovery impossible. Some aircraft are known to be susceptible to this phenomenon, and thus such training is directly applicable and critical, while others, such as the Q400 have no history of tailplane icing. The Q400 was not susceptible to tailplane stall due to design features; however, the crew was not provided this information, thus leaving them with the strong impression that the tailplane stall training was directly applicable to their aircraft.

Simulators are not required to have fidelity past stick shaker. This makes use of simulators to train pilots in full stall recognition and recovery unrealistic, if not impossible. Since this accident clearly shows that it is possible for a crew to, for whatever reason, find themselves needing to recover from a fully developed aerodynamic stall, it is apparent that airline pilots should have this elemental training. The lack of accurate depictions, information, and incorrect procedures in Colgan training materials led to misunderstanding of the specific procedure being trained and therefore inconsistent recovery techniques. The pictorial depiction of “Landing Stall” in the CFM, which describes an approach to stall recovery, but is not explicitly labeled as such, may have led pilots to the mistaken belief that this procedure could be used for stall recovery.

Recognition and recovery from full stalls is a requirement for the private pilot certificate. Some airline pilots may have not have practiced full stall recognition and recovery in decades.

The Colgan pilots were supplied with an “interim” CFM. This manual was lacking vital information needed to operate the aircraft safely and Colgan crews received no training on the additional required information in the AFM and AOM. This manual was significantly different in content, structure and design from the other aircraft operated by Colgan. The pilots were not adequately trained on the manual system approved for the Q400. Numerous variations of procedures were adopted by pilots due to the lack of clear guidance and SOPs.

The Q400 was equipped with a Reference Speeds switch to be used in icing conditions. It increased the low speed cue by 15-25 knots. This required a similar increase in approach speeds. On the accident flight, the switch was correctly set in the INCR position. The crew received and bugged the lower V_{ref} intended for use with the Reference Speeds switch OFF. This would have resulted in the low speed cue and stick shaker activation point above the bugged V_{ref} speed. This condition went unnoticed by the crew and stick shaker activation occurred. The training and procedures for setting and flying approach speeds did not discuss this critical difference and was therefore deficient. There was no consistent training or guidance provided in the CFM to crews to set speeds when using this switch. The ACARS system in use at the time allowed pilots to receive erroneously lower speeds with no error message if the keywords were inadvertently misspelled during speed requests.

The Q400 did not have, nor was it required to have certain systems that would have alerted the pilots that the airspeed was abnormally low and approaching stick shaker. An explicit angle of attack indication including pitch limit indication, although not required, would have assisted the pilots in stall recognition and recovery had one been available. Low airspeed alert and minimum maneuvering speed display provide both visual and aural alerts and indications that the aircraft’s speed is unusually low. These systems could have alerted the pilots to make an airspeed correction before reaching stick shaker.

Counter rotating propellers would have helped maintained control by eliminating or reducing left turning forces produced at low speeds. This design features could have provided a more stable aircraft, especially during low speed, high power configuration similar to the one experienced by this crew.

The design features noted above could have created extra safety margins and barriers to protect the crew from inadvertent slow speed conditions, and assisted in stall recognition and recovery.

The general working conditions of many pilots in this segment of the industry, and the accident pilots in particular, may have created economic stress that had an adverse safety impact. Both crewmembers commuted to work and remained in the crew lounge area after arriving from their respective flights. Neither had a commuter apartment, because costs to maintain a second home or obtain a hotel room are difficult to bear on the salary provided to these crewmembers. Colgan had a sick policy that was widely, if not universally, perceived by crews as punitive. This policy prohibited pilots from reporting sick within two hours of work. The conversation recorded on the CVR implied the First Officer, although she may have begun feeling ill, felt pressured to continue flying in order to get to a company-provided hotel.

The crew needed to reduce speed to configure the aircraft for the final approach. Approach phase is normally a high workload environment. The ‘Ice Detected’ status message illuminated shortly before the stick shaker. The stick shaker was a surprise to the crew. At stick shaker the autopilot disconnected, the Captain applied power and aft control column movement. The aircraft was allowed to roll to the left and pitch up substantially. This may have been due to somatagravic illusion which interfered with the crew’s perception of the aircraft’s attitude. The aircraft stalled and rolled past vertical to the left. As this occurred, the First Officer retracted the flaps. These inputs were inappropriate to a full stall recovery. However, they were consistent with an attempt at both a tailplane stall recovery and an approach to stall recovery. The stick shaker would have produced control column forces similar to a tailplane stall shown in the NASA video. The pilots had been talking about the ice accumulation on the aircraft during the approach. The icing status message had just illuminated. This would imply they were aware and cautious of the ice on the airplane. The conversation between pilots is minimal during the event, so it is not possible to know what they believed to be happening to the airplane. The stick pusher fired twice and the Captain overpowered it. He had never received training in the proper crew reaction to the pusher in the Q400 and thus was unaware of the significance of this action.

A few weeks after the accident, another Colgan Q400 flight, turned towards its landing runway and during the turn the stick shaker activated. This crew had the benefit of being in daylight with a full horizon visible. Although they had a check airman on the jumpseat, observing the crew, that pilot provided no apparent warning, suggesting the shaker was a surprise to all three pilots. Fortunately, the crew reacted appropriately, recovered and landed safely. The fact that this occurred again underscores both the propensity for this airplane and its crews to encounter a stick shaker. It appears likely that other similar events could have been expected to occur during the time the Q400 was in service at Colgan. If true, a healthy safety system would have been able to capture these events, identify the need for and provide the means to develop corrective action. The airlines resources were instead, focused on the business aspects of the rollout of a new aircraft. Management focus shifted to on-time and reliability metrics. However a poorly managed rollout in terms of training, manuals, resources and guidance stymied them. Pilots became a convenient focus of management frustrations. Guidance and actions toward pilots became punitive and arbitrary.

The FAA should have been in the position to clearly see a number of vital safety signs gone awry. However it lacked the authority to fully measure or effect the safety culture of the airline. The communication and assistance between CMO and the Division level was not effective in identifying this airline as having serious safety deficiencies. The FAA was the only entity that could provide the airline with an objective evaluation and critique of its safety culture but it did not.

Clearly, numerous factors came into conjunction on the accident flight. Opportunities for intervention in training, operations, oversight, company safety culture and even design were missed. Correcting any or all of these aspects should serve to improve the safety margins for these and similar operations.

4.0 Findings

1. The Q400 had a passive, visual low speed cue, but did not have a minimum maneuvering speed/ low speed alert.
2. The Q400 only has two airspeed bugs to be set during approach and landing, neither of which Bombardier recommends using to select the target approach speed.
3. The Q400 does not have a Pitch Limit Indicator on the EADI.
4. Colgan's Internal Evaluation Program failed to identify errors in the Captain's records, as well as its non-compliance with their FAA approved weight and balance program.
5. The Company Flight Manual issued by Colgan Air, Inc. to its Q400 pilots was incomplete and inaccurate.
6. The Bombardier Aircraft Flight Manual was not taught or provided to the pilots.
7. The Crew Resource Management program at Colgan was ineffective and outdated.
8. The Approach to Stall Training at Colgan was not accomplished or checked in accordance with the Airline Transport Pilot Practical Test Standards.
9. Stall Training and Stick Pusher Training was not conducted at Colgan Air, Inc., nor is it required by the FAA.
10. Airline pilots do not normally receive stall training and may not have practiced stall recognition and recovery since their initial flight training.
11. The FAA does not require simulator manufacturers to ensure fidelity past a stick shaker.
12. Colgan Air, Inc. showed the video “NASA In-Flight Icing Training for Pilots” during all initial and most recurrent classes.
13. The Q400 Aircraft Operating Manual contained incorrect information regarding the Q400 with respect to tailplane stalls.
14. Colgan Air, Inc. failed to provide additional Q400 specific information to pilot, with respect to tailplane stalls and differences between the Q400 and the Twin Otter from the video.
15. The Captain finished a trip the day before the accident and remained at the airport until departing on Flight 3407.
16. The First Officer commuted to Newark from Seattle during the night before the accident and stayed at the airport for the remainder of the day until departing on Flight 3407.
17. The First Officer appeared to have been sick, but did not remove herself from her trip. This was likely due to the punitive nature of Colgan’s sick policy.
18. The pilots were properly certified and qualified under federal regulations and Colgan Air, Inc. training requirements.
19. The flight was operated in icing conditions and the aircraft icing equipment was on and operating properly.
20. Aerodata electronic landing data would send non-icing speeds if a crew misspelled the keyword "ICING or EICE." The ACARS request sent by the accident crew was not available to the investigation.
21. The icing conditions encountered were within the operating/ certified limits of the aircraft and had a minimal effect of the performance of the aircraft.

22. At the time of the autopilot disconnect/ stick shaker activation, the flight was being operated at night in instrument meteorological conditions.
23. At the time of the autopilot disconnect/ stick shaker activation, the power levers were near idle and the flaps were transitioning from 5°-10°.
24. Subsequent to the autopilot disconnect/ stick shaker activation, the power levers were advanced to 75% and were not in the detent.
25. Subsequent to the autopilot disconnect/ stick shaker activation, the aft control column was moved aft and did not go forward of the neutral column position throughout the entire event.
26. Subsequent to the autopilot disconnect/ stick shaker activation, the First Officer raised the flaps to 0°.
27. The Captain applied Control Wheel inputs to correct the roll excursions, but each time the aircraft went through wings level and continued to roll in the opposite direction.

5.0 Recommendations

As a result of this investigation, the Air Line Pilots Association, International suggests that the NTSB make the following recommendations.

5.1 Recommendations to the Federal Aviation Administration

1. Ensure that airline initial pilot training programs provides sufficient classroom and simulator training to provide the knowledge and skill necessary to perform proficiently *prior* to initial operating experience (IOE). Integration training to merge skills and knowledge necessary for the expected operational environment should occur prior to IOE.
2. Require airlines to develop and implement tailored training that accommodates and adjusts to variations in student's backgrounds, experience and prior training.
3. Require airlines to provide first officers with the same type rating required by captains.
4. Eliminate the "SIC privileges only" rating.
5. Require airlines to train first officers to the same standards and receive proficiency training at the same intervals as captains.
6. Monitor airlines to ensure a culture exists that promotes and nurtures the highest levels of safety and professionalism by both pilots and their managers. Guidance should be provided from the Branch level of the FAA.
7. Require a Low Speed Alert (Min Maneuvering Speed) be incorporated into existing aircraft, if possible.
8. Require manufacturers to incorporate a visual cue to the margin to stick shaker, i.e. Pitch Limit and Angle of Attack indicator, in existing and future aircraft.
9. Require airlines to provide aircraft training and practice in various levels of manual and automated flight modes. This training should embody techniques and practices that allow the ability to competently monitor, track, and manage automation and to recognize the strengths and weaknesses of its use or non-use.
10. Require airlines under Part 119 to employ a Director of Pilot Training who is specifically responsible for the functions, content, and direct oversight of the pilot training program. This person should have skills and training in developing, evaluating and conducting educational courses.
11. Develop with industry an enhanced ground school and testing requirements to qualify to be an airline instructor.
12. Require airlines to develop and implement improved instructor screening processes and instructor training to ensure that motivated and highly skilled instructors are provided to train their line pilots.
13. Require airline training pilots and instructors to have a current Certified Flight Instructor Certificate appropriate for the type of training they provide.
14. Require airlines to incorporate Safety Management Systems (SMS).
15. Require simulator manufacturers and aircraft manufacturers to enhance simulator fidelity in regimes outside normal flight so that maneuvers, such as aerodynamic stalls, can be trained, practiced, and evaluated in a realistic manner.
16. Require aircraft manufacturers to hold operator conferences and require airlines and regulators (POIs/APM) to participate in these conferences.
17. Require airline managers with operational authority to conduct jumpseat line observations of the operation on a periodic basis.

18. Require airlines to provide specific command training courses for new captains which provide skills to lead, manage and prioritize on the flight deck. In addition to basic skills such as aeronautical decision making and crew resource management, new captains should receive training to reinforce the skills, aptitudes, judgment, and professionalism necessary to properly lead a crew, exercise command authority, and maintain the highest levels of safety in the face of internal or external pressures.
19. Require the Director of Safety at a Part 121 carrier to have an airline transport pilot rating and have a completed a certified aviation safety certificate program or equivalent courses at a university or military.
20. Conduct a review of all airline training to ensure that it meets the requirements of the Practical Test Standards (PTS).
21. Ensure airline training programs conduct stall training in the different regimes of the operating envelope of the aircraft, including but not limited to stalls during departure, stalls in the during final approach, high altitude stalls.
22. Ensure that airlines have a clear, concise non-punitive sick and fatigue policies.
23. Require airlines to incorporate fatigue training/ mitigation for flight crew members, flight attendants, mechanics, dispatchers, schedulers, and all operational managers.
24. Develop with industry a module in their CRM training program to include sterile cockpit, active monitoring, and the handling of distractions.
25. Require each airline evaluate their various communications methods with flight crews and ensure that for any procedural/ policy changes, flight crew members are provided individual copies (electronic or hard copy), which can be referenced in-flight.
26. Require airlines that provide general knowledge information or videos (i.e. tailplane stall training) to also provide aircraft specific training in the differences from the general information (i.e. flight controls, recognition characteristics and recovery techniques)
27. Require airlines to provide pilots with information on the handling characteristics of their aircraft, as affected by airframe ice accretion.
28. Collect information on airline's compliance with SAFOs, AC, as well as safety programs (ASAP, FOQA, LOSA). That information should be disseminated to CMOs.

5.2 Recommendations to Bombardier

1. Modify the Q400 software to allow V_{fri} and V_{cl} to be bugged.

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Appendix A: Colgan Pilot Base Closures

Base	Date Closed
ABE	Closed 4th Quarter 2009
AOO	Closed 3rd Quarter 2007
AUG	Closed 4th Quarter 2008
BGM	Closed 4th Quarter 2009
BKW	Closed 3rd Quarter 2007
BOS	Closed 4th Quarter 2008
BWI	Closed 4th Quarter 2008
HEF	Closed 1st Quarter 2008
HPN	Closed 1st Quarter 2009
HYA	Closed 1st Quarter 2008
ITH	Closed 3rd Quarter 2009
JHW	Closed within past two years
JST	Closed within past two years
LEB	Closed 2nd Quarter 2008
ORF	Closed 3rd Quarter 2009
PIT	Closed 4th Quarter 2008
PVD	Closed 3rd Quarter 2009
ROC	Closed within past two years
SCE	Closed 4th Quarter 2009
SHD	Closed 4th Quarter 2007