Friday, April 12, 2002

Mr. Alfred Dickinson
Investigator-In-Charge (IIC) CMR 5054
Major Investigations Division
National Transportation Safety Board
AS-10 Room 5305
490 L'Enfant Plaza East, SW
Washington, DC 20594-003

Dear Mr. Dickinson:

In accordance with the Board's rules, the Air Line Pilots Association submits the following comments concerning the accident involving Comair Airlines Flight 5054, which occurred on March 19, 2001 near West Palm Beach, Florida.

On March 19, 2001, an Embraer EMB-120, operating as Comair Flight 5054, was en route with the autopilot engaged from Nassau, Bahamas to Orlando, Florida and encountered icing conditions after descending from the altitude of 18,000 feet to 17,000 feet. During the icing encounter, the airplane began to slow and the autopilot began trimming the elevator to maintain altitude. The airspeed continued to deteriorate, the airplane departed controlled flight. The crew then disconnected the autopilot. After taking over manual control of the aircraft, the crew attempted to recover control by reducing the angle of attack and increasing power but found that the control wheel was extremely difficult to push forward. At this time the airplane began to experience significant roll excursions as it descended to approximately 10,000 feet in IFR conditions (a loss of 7,000 feet) before exiting the clouds, which then enabled the crew to determine their attitude and a recovery procedure by visual reference, since during the aircraft upset the airplane's Electronic Attitude Display Indicator (EADI) had blanked out.

The flight crew diverted to West Palm Beach where the airplane was landed without difficulty. During the post-flight inspection the crew observed that the aircraft had received significant damage and noted that the airplane had apparently suffered permanent deformation of the elevator and stabilizer during the uncontrolled descent.

The key area of concern regarding this nearly catastrophic accident must be the failure of a critical flight instrument (EADI) during a critical phase of flight. This is not the first time it has happened. It must also be reiterated that it has been over 5 years since the accident of Comair 3272, as well as the Westair 7233, which both made clear that the EMB-120 has significant flight handling qualities in icing conditions. For example, Comair flight 3272, and Westair flight 7233 both had similar loss of control in icing conditions. This was almost another catastrophic accident of an EMB-120, which has a history of 20 years of handling problems in icing. Neither the FAA nor the manufacturer have corrected this problem of poor handling, nor does ALPA believe that the past recommendations by the NTSB have been adequately implemented.

Most unfortunate is that the recommendations from the investigation of Comair 3272 if implemented may have prevented this accident. We will revisit many of the issues raised in the prior investigations, as well as raise some additional issues unique to this accident. We will address the airplane's behavior in icing, the airplane's high computed weight at takeoff (in light of suspected higher passenger and bag weights), the autopilot and the trim system function causing the crew to have an excessively challenging situation upon the autopilot being disengaged, and the inability to forecast and identify the severe icing experienced on this flight. ALPA will endeavor to address each of these subjects, which will support the recommendations we provide at the end of the attached report.

The airplane is in continuing service in the US as well as with other carriers around the world, and thus needs corrective action, to its design and systems. These changes must be seriously considered and implemented in order to resolve this recurring handling problem. The airplane may need an increase in deicing boot size or some change in control system to improve its handling to function adequately in accordance with conditions of Appendix C of Part 25.

It is our sincere wish to see that we learn from this accident so that there are no similar events in the future where the outcome is not so fortunate. We wish to meet with the Board members to discuss these issues further. We appreciate the continued efforts of NTSB to achieve this goal.

Here follow our recommendations developed regarding this accident.

Recommendations

1. We urge the Board to examine all accidents of airplanes involving inflight loss of control and the ensuing aircraft dynamics to determine the appropriate possible roll and pitch rates that may be experienced, and to provide that data to the SAE A-4 Aircraft Instruments Committee for updating the AS 8001.
2. The product manufacturer, Collins, should communicate the product limitations to the aircraft operator, and the operator should communicate those limitations to the end users, the pilots.
3. Further, the product manufacturer, Rockwell Collins, should redesign their product, the AHRS EADI system, to provide useful information without any disruption/discontinuity of its attitude display. The attitude information provided by the EADI should continue to display when a monitor exceedance occurs, though it may lag actual aircraft attitude. It should display continuously and resynchronize with actual aircraft attitude upon the roll rate exceedance no longer existing.
4. The manufacturer should develop a modification to the aircraft warning systems to make an aural alarm to indicate that the horizontal trim is in motion.
5. The manufacturer should modify the logic in the stall warning system for the EMB-120 to decrement the angle of attack at which the stall warning system activates the stick pusher so that the airplane cannot approach the stalled condition when in icing environmental conditions.
6. The training program at all air carriers operating this type of EADI should be revised to reflect that the EADI may blank out if its roll or pitch rate limits are exceeded.

7. Training should also include direction to check the control surface trim positions immediately upon disconnecting the autopilot either intentionally or as a result of the autopilot reaching its authority limits.
8. Further research and development is needed regarding forecasting and prediction of icing in subtropical regions.
9. Systems and methods should be developed to enhance a crew’s ability to detect and avoid icing conditions that exceed the demonstrated capability of the airplane.
10. Flight crews should be provided real time weather charts with detailed icing information included.
11. The deicing boots of the EMB-120 should be redesigned by increasing their coverage area to ensure that they can maintain the wing free of ice.
12. The manufacturer should develop a system to alert the crew when the ice protection system is not effectively protecting the airplane from ice accretion that results in the increase of drag during the icing encounter.
13. The FAA should require airlines to conduct periodic passenger and bag weight surveys that are specific to the routes flown.

Best regards,

Captain Steve Marshall
ALPA Coordinator

Cc: T. Haueter
V. Ellingstad
J. Clark

SUBMISSION OF THE

AIR LINE PILOTS ASSOCIATION

TO THE

NATIONAL TRANSPORTATION SAFETY BOARD

REGARDING THE ACCIDENT INVOLVING

Comair Flight 5054

OFF WEST PALM BEACH, FLORIDA

ON MARCH 19, 2001

ALPA Submission on Comair Flight 5054, EMB-120
West Palm Beach, Florida, March 19, 2001

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ALPA Submission on Comair Flight 5054, EMB-120
West Palm Beach, Florida, March 19, 2001

Overview

Comair Flight 5054 departed Nassau, the Bahamas (NAS) on March 19, 2001 at about 1720 local time[1]. The airplane was an EMB-120, aircraft serial number 1258. The flight plan was to climb at 190 KIAS to flight level 180 and cruise at max speed until making the approach into Orlando, Florida (MCO), the scheduled destination. The flight diverted after the inflight upset (detailed below) into West Palm Beach International Airport, Florida (PBI).

The inflight upset which is at the core of this accident occurred after the crew was cleared to descend from FL 180 to 17,000 feet, while in Instrument Meteorological Conditions (IMC). The decision to descend was due to the airplane experiencing turbulence at 18,000. The weather in the area had large areas of cloud with some embedded rain cells. Prior to the upset, the airborne weather radar was painting a cell 30 degrees to the left of course, about 40 miles away, as described by the captain in his interview statement.

On the prior flight from MCO to NAS, this same airplane and crew (except the flight attendant, who was changed in NAS) had flown into, and had noted some normal ice accretion. There was some ice shedding recalled by passengers on the previous flight, as noted by the sound of ice off of the props hitting the sides of the fuselage.

After the crew was cleared to descend to 17,000 feet, the air temperature increased slightly. The temperature at 18,000 had been about -5?C in the minute prior to the descent, and then the temperature at 17,000 was about-4?C for the 7 minutes prior to the upset at that altitude. The captain reported in his interview that he asked the flight attendant for some coffee. The flight attendant came to the cockpit and at this time noted that the windshield had some ice accretion, which the captain described as pebble-style rime ice. At that time the crew noted this ice formation and set the ice protection systems on (windshield, de-icing boots, prop and pitot heat) as required by the checklist. The ice was observed to melt on the windshield. The ice detection light then illuminated and after about a minute, extinguished. The airplane was on autopilot at the time, as is normal in this phase of a flight. (The autopilot is a full authority autopilot but is not equipped with autothrottle. This autopilot and its interaction with the crew and the other airplane systems will be further addressed below).

Shortly after the flight attendant brought the captain his coffee, the first officer noted to the captain that the airspeed was dropping. The captain saw the airspeed dropping past 160 KIAS and grabbed the controls and disconnected the autopilot. The captain increased the power. The airplane did not stop decelerating and began to roll about its longitudinal axis. The captain noted an unusual buzzing in the control wheel which he had never experienced before.

The captain had not noted any movement of the horizontal stabilizer trim wheel, but in fact the horizontal stabilizer trim had been moving during the prior 2 minutes from 0 to nearly 7 degrees, so that at the time that the autopilot disconnected, it was at a setting that made the airplane handling qualities extremely challenging. The aircraft was not equipped with an aural alert, clacker, or horn, etc., to alert the crew of the trim change. (See Systems section below).

[1] 2220 UTC (1720 Local (Local time = UTC –5 hrs)) and the scheduled departure time was 2100 UTC (1600 Local).

After the captain increased the power the airplane continued to decelerate and reached the minimum airspeed of 130 kts. The airplane had rolled to a bank of 80 degrees left wing down, though the power was set at 82.9% and 77.8% (left and right engines). After this, the airplane rolled in repeatedly higher bank angles, briefly rolling at a rate of 162 degrees per second while at a momentary descent rate of approximately 312 feet/sec (18,750 ft/min). Fortunately, the crew was finally able to recover at 9,500 feet upon reaching visual conditions where they could determine the aircraft attitude by visual reference, as their attitude instrumentation was useless.

Upon leveling off, ATC still had the flight at 17,000 feet, due to radar system software overriding the transponder data indicating the altitude around 10,000 feet. The crew requested vectors to land at the closest customs entry port and flew the airplane to Palm Beach International airport (PBI).

The investigation that followed raised numerous issues which were also included in our submission to the Board regarding Comair flight 3272, in Monroe, Michigan. Some recommendations from that investigation were implemented, and others were not. Clearly, the recommendations implemented were not sufficient to prevent a recurrence of nearly the same accident as that in Monroe. It is fortunate that this accident was not at a lower altitude when it occurred or it would have been fatal. Thus, it is imperative to reexamine the issues raised in the investigation of Comair 3272 and the issues further identified herein. We urge you to consider these arguments and the recommendations that conclude the report in determining the appropriate recommendations to issue from the Board.

Systems

Attitude Heading Reference System (AHRS) Certification

The issue of AHRS causing the EADI to blank out when excessively high rates of roll or pitch change indicate a problem that could exist in a large number of aircraft models in commercial operation. The same basic system as noted is in use on the Canadair RJ, the Fokker F-100, the Saab SF-340, and is an option on the ATR-42/72 and the Beech B-1900.

The Rockwell Collins Electronic Attitude Display Indicator (EADI) was installed on the accident airplane. This system consists of the sensing computers which supply information to the data processing unit which drives the two EADI displays, one in front of each pilot. In the subject event, the EADIs "blanked out" during the upset from stable flight, resulting in intermittent indications to the crew and a lack of pitch attitude reference which resulted in the crews inability to recover. The certification standard appears to be at fault. The EADI must function at realistic but high rates of change of aircraft attitude and should not fail abruptly upon exceeding the certified limits of performance.

The EADI functions as the primary attitude indicator for the crew. Each pilot has a display and its supporting equipment. The EADI is advertised to function at up to 128?/sec in pitch, roll and yaw. The bench tests of the EADI sensors (AHC-85, Attitude Heading Computer) reported in the factual report of the Airworthiness Group Chairman's factual report revealed that the copilot's AHC "would not initialize due to excessive pitch error"[2]. The captain's AHC "flagged at

[2] pg. 15, Airworthiness Group Chairman's factual report

approximately 40 ?/second . . . The unit failed to meet the design requirement in that the flag should not have been seen until rates in the range of 128 degrees/second in either direction."

The following figure (Figure 1) shows the elements displayed on the EADI.[3]

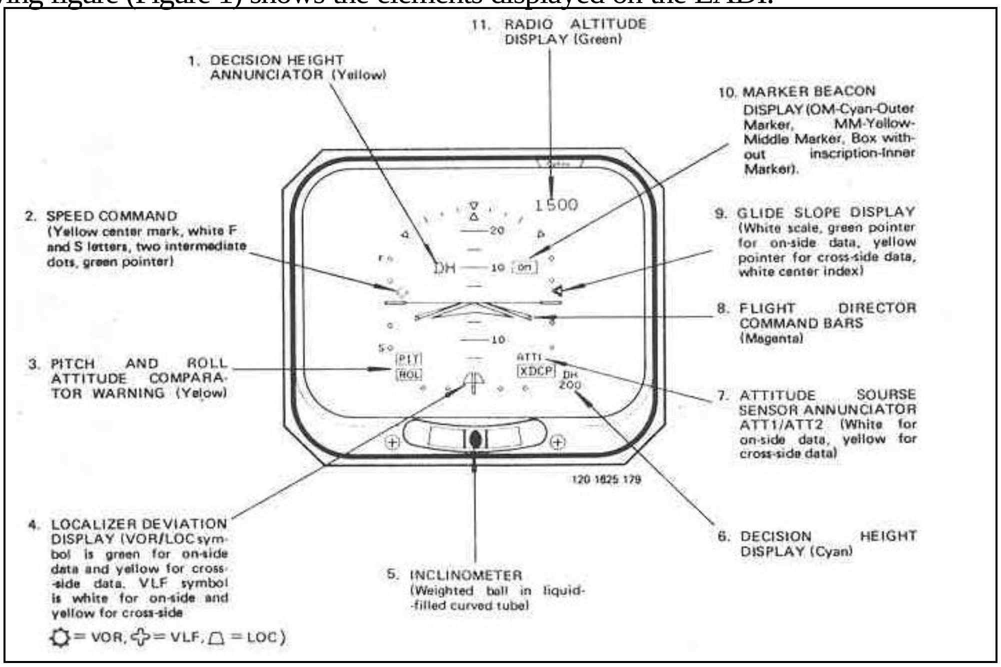

Figure 1

Systems: AHRS Applicable Standards

The EADI is approved for service as part of the aircraft airworthiness type certificate. The AHC-85 computer in the EADI was approved under Technical Standard Orders (TSO) TSO-C4c - BANK AND PITCH INSTRUMENTS (dated 4/1/59) and TSO-C6c, DIRECTION INSTRUMENT, MAGNETIC (GYROSCOPICALLY STABILIZED), ('d' version dated 6/14/89). The TSO-C4c refers to the standards set forth in SAE Aeronautical Standard AS-396B, "Bank and Pitch Instruments (Indicating Stabilized Type) (Gyroscopic Horizon, Attitude Gyro)," dated July 15, 1958 which is marked as "NONCURRENT" as of July 2001.

The TSO TSO-C113, AIRBORNE MULTIPURPOSE ELECTRONIC DISPLAYS provides reference to SAE Aerospace Standard (AS) document No. AS 8034, "Minimum Performance Standard for Airborne Multipurpose Electronic Displays," dated December 30, 1982. However, this TSO is not referenced in the manufacturer's product literature.

The SAE Aeronautical Standard AS-396B, "Bank and Pitch Instruments (Indicating Stabilized Type) (Gyroscopic Horizon, Attitude Gyro)," dated July 15, 1958 is marked as "NONCURRENT" as of July 2001. It does not specifically set any requirements for instrument response time in rapidly changing environments. The AS-396B refers only to Turn Error and Settling Error. It states the following.
"Turn Error: The bank or pitch indicating error resulting from a coordinated turn of 180 degrees in one (1) minute at a true airspeed of 180 mph (156 knots) shall not exceed 3 degrees."

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[3] Embraer EMB-120 Operations Manual, section 6

"Settling Error: When the gyro has erected and attained equilibrium speed and the indicator and/or the gyro component has been oscillated on a roll, pitch and yaw, simulator through an angle of ± 7½ deg. About each axis at a frequency of 5 to 7 cycles per minute for 30 minutes and then returned to level position, the alignment of the bank and pitch indicators with their respective zero indices shall be within one degree."[4]
Five cycles per minute with an amplitude of 7 ½ degrees results in a 15 degree range every 12 seconds, or 1.25?/sec. This low rate of change for pitch, roll and yaw are inappropriate. The test conditions must be representative of the worst-case scenario for which the operation of the system is necessary. The following review of the accident/incident history will elucidate this.

Accident Experience

The subject aircraft, an EMB-120, had several roll oscillations of increasing amplitude. During these uncontrolled roll events, the airplane was also pitching around an axis horizontal and perpendicular through the fuselage, that is as caused by the elevators, engine, and flaps, etc. The roll rate for the accident airplane reached as high as 163?/sec. There have not been any other accidents in which the roll rate was this high, however, there have been several other accidents involving loss of control that necessitate our requesting that work be done to ensure that EADI and similar equipment be proven to function at roll and pitch rates up to those experienced in the subject accident.

Aircraft Roll Rate

While the roll rate of the subject accident may seem extremely high, it should be put into proper perspective along with the declared capabilities of the AHRS unit. The AHRS unit was advertised to function up to 128?/sec. This equates to a full 360 roll in just under 3 seconds (2.82 sec). Aircraft are most easy to move around the longitudinal axis, i.e., the one affected by rolling. Further, as an aircraft experiences an imbalance of lift forces on the wings due to one wing stalling prematurely, it results in a rolling motion. While normal flight control inputs on air transport airplanes achieve roll rates around five degrees per second, the accident record shows that when an imbalance of lift occurs, due to a stalled wing, or large rudder inputs, the roll rate can become much higher. Table 1 shows previous accidents that have demonstrated high roll rates.

Date	Type Airplane	Flight ID	Location	Roll Rate, ?/sec
9/8/94	B-737	USAir 427	Aliquippa, PA	43
10/31/94	ATR-72	Simmons 4184	Roselawn, IL	72
12/22/96	DC-8-63	Airborne Express	Narrows, VA	22
12/9/97	EMB-120	Comair 3272	Monroe, MI	78
1/31/00	MD-83	Alaska Airlines 261	Port Hueneme, CA	60

Table 1

The EMB-120 accident of Continental Express Flight 2733, at Pine Bluff, AR, on 4/29/93 also has relevancy. Further, it should be noted that intentional roll rates of 400?/sec can be achieved in modern aerobatic airplanes.[5] Such roll rates resulting from aerodynamic forces under

[4] Paragraphs 4.5 7 6.2, SAE AS-396B
[5] Aviat S-1-11B roll rate is somewhere around 400°/sec.

intentional circumstances on small airplanes simply demonstrate high roll rates can be achieved. Roll rates would be less for larger aircraft. The point in noting these high roll rates is that it shows the high rates are not intolerable to flight crew and additionally provide an extreme limit for potential roll rates.

The following recommendation is relevant regarding the EADI failure. The NTSB summary and recommendation are as follows:

On May 12, 1997, at 1529 eastern daylight time, an Airbus Industrie A300B4-605R, N90070, operated by American Airlines as flight 903, experienced an in-flight upset at an altitude of 16,000 feet near West Palm Beach, Florida. During the upset, the stall warning system activated, the airplane rolled to extreme bank angles left and right, and rapidly descended more than 3,000 feet. One passenger sustained serious injuries, and the airplane received minor damage. Flight 903 was being conducted under the provisions of 14 CFR Part 121 as a domestic, scheduled passenger service flight from Boston, Massachusetts, to Miami, Florida.

That recommendation is quoted here:
A-98-3 Require that Airbus Industrie modify the symbol generator unit (SGU) computer software installed in the A300 so that an unreliable data reset of the electronic flight information system will not occur during an upset. When the modified software is available, require that all operators install it in the SGUs.

The status of this recommendation is OPEN ACCEPTABLE RESPONSE. The FAA indicated that they intend to issue an Airworthiness Directive (AD) to implement an Airbus Service Bulletin to correct the software from issuing an order to reset the SGU as a result of high airplane rate input data being interpreted as suspect, which caused the captain's and first officer's Primary Flight Displays to go blank for up to 4 seconds.

The FAA recently issued the AD noted above[6]. In it, the FAA stated that: “Temporary loss of data from the primary flight displays and navigation displays could cause the flightcrew to have inadequate flight information. Inadequate flight information could result in reduced situational awareness for the flight crew, which could contribute to loss of control or impact with obstacles or terrain.” This argument is equally applicable to the subject EADI failure. The EADI should be able to function at rates up to those that can be survived, by the crew and the airplane. Thus we conclude that the standards for the EADI should be reexamined with this in mind.

The flight recorder data for this event should be reviewed to determine the roll rates experienced in this case.

State-of-the-Art: Standards for Attitude Indicator System Responsiveness

Reference to the SAE Aerospace Standard 8001, Minimum Performance Standard for Bank & Pitch Instruments, shows that an improved standard over SAE AS 396B exists, however, this standard still does not require roll rate testing at levels experienced in this and other accidents.

[6] Federal Register/Vol. 67, No. 64/ Wednesday, April 3, 2002, Docket No. 2001-NM-348-AD

The paragraph 4.7 on Roll Maneuver Error calls for a roll rate of 15 – 20 degrees per second through 360 degrees with an immediate resultant accuracy of not exceeding 2 degrees.

There is an ARINC specification for electronic attitude indicators that reportedly directs that roll attitude may only provided valid data up to a nominal rate of 70?/sec.

Conclusions

The EADI for this airplane failed at a very inopportune time. Successful recovery of control after an airplane experiences an excursion from controlled flight depended on the crew being provided accurate attitude information. Failure of the primary attitude indicator is unacceptable under dynamic aircraft conditions reasonably confronted during flight, even if only during excursions from controlled flight.

Recommendation

1. We urge the Board to examine all accidents of airplanes involving inflight loss of control and the ensuing aircraft dynamics to determine the appropriate possible roll and pitch rates that may be experienced, and to provide that data to the SAE A-4 Aircraft Instruments Committee for updating the AS 8001.

EADI Failure Indications to the Crew

The EADI failure was unexpected and resulted in confusing the crew, due to the clutter/declutter function working independently of the loss of source flag experienced.

The EADI has several failure/error messages that display on the screen. In postflight interviews of the crew, the crew was not certain of the message that they saw during the roll excursion. The EADI failure messages are displayed in the following format from the Embraer EMB-120 Operations Manual.

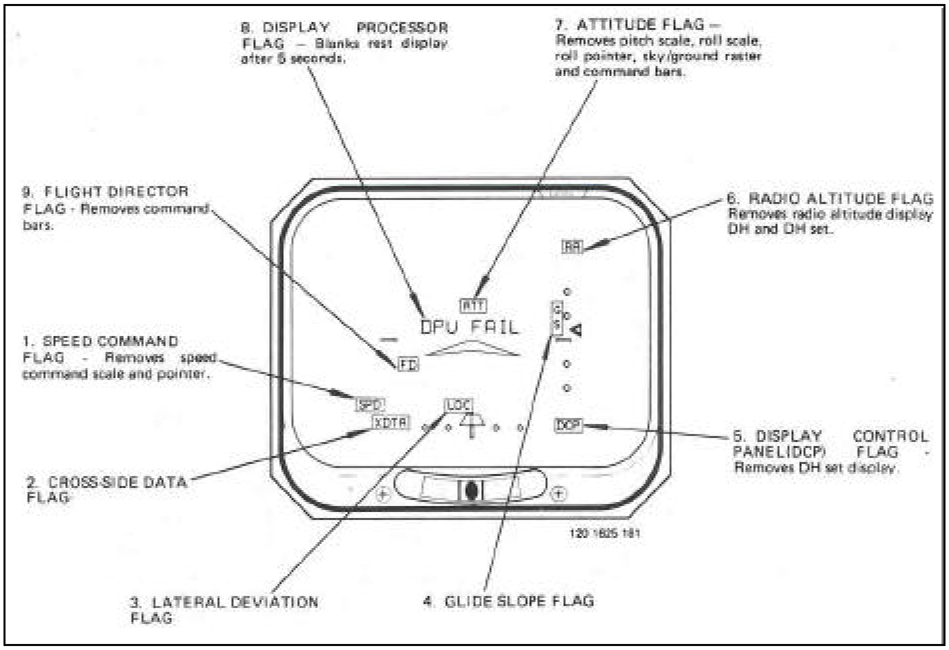

Figure 2

The Embraer EMB-120 Brasilia Operations Manual has a section on Abnormal Procedures, specifically for Nav/Flight Instruments Failure (pg. 3-45). For the Collins EFIS configuration (which applies to the subject airplane), it presents the following for the EADI.

Flag/ Annunciator	Reason	Action
ATI (red)	Attitude Source failure	Use cross-side attitude, selecting XFR position on AHRS ATT transfer switch (EFIS control panel)
FD (red)	Flight director system failure	-
RA (red)	Radio altimeter system failure (if installed)	-
SPD (red)	Stall warning system failure	-
LOC, VOR, VLF (red)	NAV source failure	Select another source
PIT or ROL (yellow)	Pitch or Roll comparator error	Resent through ATT/HDG MONITOR Switch

Table 2

There are similar tables for other components. Note that there is no flag or reason indicating that both of the EADI would fail due to rate exceedance.

The AFM from Embraer describes the ATTitude Flag as follows: “7. ATTITUDE FLAG – Should the attitude source fail, the attitude display and command bar disappear and ATT flag will appear. This flag will remain until an alternate source is supplied or until the fault is cleared.”

The Embraer EMB-120 Brasilia Operations Manual has a section on Normal Procedures, after start. It presents the following for the EADI.

Instruments . . . . SYNC AND X CHECKED

Pilot and copilot cross-check their flight instrument.

?? EFIS/AHRS Transference (EFIS configuration) . . . . . CHECKED

Position DISPLAY SOURCE transfer switch to XFR, and chek XFR light illuminated. Return the switch to NORM and repeat the procedure with AHRS ATT and AHRS HDG transfer switches.

AC 25-11 Transport Category Airplane Electronic Display Systems

This AC was published in 1987, initiated by ANM-110. It includes in its scope guidance related to pilot displays. It specifically addresses clutter (the abundance of messages and symbology in the display), attention getting requirements, and failure modes.

Section 4 of AC 25-11, on General Certification Considerations, begins with a paragraph on Display Function Criticality. It states that: "Although normal operation of the airplane may become easier, failure state evaluation and the determination of criticality of display functions may become more complex." It goes on to state that: "Criticality of flight and navigation data displayed should be evaluated in accordance with the requirements in Secs. 25.1309 and 25.1333 of the FAR. Advisory Circular 25.1309-1 clarifies the meaning of these requirements and the types of analyses that are appropriate to show that systems meet them."

The AC paragraphs quoted here indicate that the EADI must provide accurate attitude information to the crew throughout the potential flight envelope. In fact, it is in the loss of control event scenario where the information on attitude in a rapidly changing condition is most necessary.

Section 7 of AC 25-11, on Information Display, paragraph 4.(e)(1) directs that the EADI will be available continuously through all attitudes. It states it as follows regarding attitude display: "An accurate, easy, quick glance *interpretation of attitude should be possible for all expected unusual attitude situations and command guidance* display configurations." (Emphasis added)

Paragraph 4.(f) of AC 25-11 on Digital, Analog, and Combination displays refers to human factors/ergonomics considerations regarding human perception of display information. It states in part that "Digital information displays will be evaluated on the basis that they can be used to provide the same or better level of performance and pilot workload as analog displays of the same parameters." ALPA understands the guidance of this statement to be that in the event of the digital system capability being exceeded, it should fail in a manner comparable to that of the analog system if it were in place. Having the digital system fail by blanking out and displaying the "DPU Fail" message box in the center of the display does not seem to be in accordance with this guidance.

The regulation 14 CFR 25.1333 on instrument systems states in part that:

> For systems that operate the instruments required by § 25.1303(b) which are located at each pilot's station -
> (b) The equipment, systems, and installations must be designed so that one display of the information essential to the safety of flight which is provided by the instruments, including attitude, direction, airspeed, and altitude will remain available to the pilots, without additional crewmember action, after any single failure or combination of failures that is not *shown to be extremely improbable*;[7]

ALPA understands this to mean that the EADI should function without disruption in service under conditions where its need is most critical, i.e., during an inflight loss of control, and that the reliability estimation must be done in environmental conditions representative of loss of control scenarios.

The issue of the EADI blanking should be considered in light of the guidance from AC 25-11 Section 8 on Switching and Annunciation which states the following regarding Power Bus Transients: *"The electronic attitude display should not be unusable or unstable for more than one second* after the normally expected electrical bus transients due to engine failure, and should affect only displays on one side of the airplane. *Recognizably valid pitch and roll data should be available within one second, and any effects lasting beyond one second should not interfere with the ability to obtain quick glance attitude*." The AC then provides a scenario with which to illustrate *why* the EADI is most needed in the event of an aircraft departure from controlled flight. It states that: "For most airplanes an engine failure after takeoff will simultaneously create a roll rate acceleration, new pitch attitude requirements, and an electrical transient. Attitude information is paramount; transfer to standby attitude or transfer of control of the airplane to the other pilot cannot be reliably accomplished under these conditions in a timely enough manner to prevent an unsafe condition." This sets the scene for how the EADI should be evaluated to function. This paragraph clearly shows that the intent for the attitude display is for it to function without more than a one second disruption in display upon the airplane experiencing a divergence from normal flight. This same level of performance should be required for roll and pitch excursions.

Interview Notes Regarding the EADI Operation

The crew for CMR 5054 stated that during the upset, the EADI blanked out and was intermittent. The F/O was recorded as having stated in the Operations Group factual report that at the beginning of the upset "He said that, at one point, he saw the attitude indicator was all brown with the arrows pointing to the sky. Several times the attitude indicator would show some blue. The attitude indicator picture was changing fairly rapidly at that point." The F/O stated that later "During the event, he said that both of their EADI "blanked out". During the event, he saw some red flags on the EADIs, but could not recall what the flags said. He remembered glancing over at the captain's EADI and it had the same indications. They were still in IMC at that time. He said he did not look at the standby flight instruments when everything went "blank".

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7 [Amdt. 25-23, 35 FR 5679, Apr. 8, 1970, as amended by Amdt. 25-41, 42 FR 36970, July 18, 1977]

"About three or four seconds after the EADI screens went "blank", they came out of the bottom of the clouds and recovered on outside visual cues. There was not a hard visual horizon picture but there was something they could fix on in the cloud line. Seconds after they leveled off, the EADI screens came back on and there were no flags. It was as if nothing had happened to the EADIs."

The captain recalled the EADI blanking as follows: "The airplane rolled to the right and the nose went down. His EADI went "blank" and he saw the first officer's EADI was "blank" also. He said his EADI would occasionally flicker back on momentarily and he kept hoping it would come back on. The EADI had red flag failures on the "blank" screen. He only recalled the EADI tube going blank. The horizontal situation indicator (HSI) appeared to be okay. He did not look at his standby flight instruments during the event."

The Operations Factual report documented the simulator operation specifically regarding the EADI as follows: "The EADI was then demonstrated. When the EADI was blanked out by loss of power to the instrument, there was no attitude or any other information at all on the instrument." This training represented the only type of EADI failure that the crew would expect to observe. The fact that the crew in this accident was faced with observing an EADI with blanking and independently functioning clutter/declutter action occurring resulted in a high state of distraction for the crew, which understandably resulted in the crew not redirecting their attention to the standby attitude indicator.

This factual report further stated that "When the simulator was put into an unusual attitude where the bank angle was in excess of 60 degrees, the EADI would "declutter" and the instrument would only have the following indications: blue color to indicate sky and brown color to indicate ground, a sky pointer to indicate the direction of the sky, and a airplane symbol that indicated the position. When the simulator was put into an unusual attitude where the pitch was more than 30 degrees above the horizon, the EADI again "decluttered" with the same indications plus red chevrons appeared on the instrument pointing downward to indicate the airplane pitch should be decreased.

"When the simulator was put into an unusual attitude where the pitch was more than 15 degrees below the horizon, the same "declutter" occurred and this time the red chevrons appeared pointing upward. As the pitch was allowed to continue below 90 degrees below the horizon, the same indications were present except the chevrons became larger in appearance. During the entire pitch down demonstration, there was always a blue color on the indicator indicating the direction of the sky."

Further, there were several interviews with personnel from the Comair training department that provide more background on how the flight crews are taught that the EADI functions. The following bulleted items are excerpted from those interviews.

?? During that instrument training they taught pilots that if they had a failed attitude instrument, they should refer to the stand-by instrument and do what was appropriate to troubleshoot the malfunction. He said that they taught the procedure to transition to the standby instrument but they did not teach the technique of flying on the standby instrument and did not fly an approach on it. He said, outside of the instrument training, they never failed the EADI and there were no maneuvers or scenarios where EADI was failed and the pilot must complete the maneuver on the standby. They had never failed the EADI during upset training. He said it was not his normal training to fail both EADIs at the same time.[8]

?? On the EADI, when you exceeded a certain bank angle, you were left with the blue/brown, pitch information and an airplane indicator. All non-attitude related info on the display was removed (fast slow indicator, runway depiction, course deviation indications, etc). He has never seen the EADI blank out during any of his line flying in the airplane or in the simulator. The only instance he has heard about this ever happening was related to the accident under discussion. They were not trained in the limitations of the EADI and under what conditions it would blank out. He learned about the limitations after the accident while working as part of the FDR group.[9]

?? Pilots see an upside down presentation during the unusual attitude training. He said that when you were upside down, you still had an indication of your shortest direction to the horizon, but your momentum may force you into a complete roll. He said there was no procedure with respect to recovering from a roll excursion (whether to continue the bank all the way around or to correct back the other way).[10]

?? He had never experienced an EADI blanking out. He was not sure if he had heard of one blanking out other than this accident. No other reports had come in. During training students are not told about the possibility of an EADI blanking out. He said he did not know of parameters that would blank out the EADI so he could not teach them.[11]

?? He did not provide any instruction on the limitations of the EADI that might cause a "blanking out", as he was not aware of it happening or any limitations associated with it.[12]

?? His recall was that neither he nor anyone else had never had the EADI "blank out" in flight or at any time. He was not aware of any limitation that might blank it out other than a systems failure. If an EADI, failed he would expect the pilot to go to the standby attitude indicator and that was how they trained. In the simulator, they allowed the pilot to fly on the standby attitude indicator for a while. The length of time using the standby indicator depended on the comfort level of the student but there were no approaches or maneuvers specifically flown using the standby attitude indicator.[13]

Conclusions

The instructors indicate that while pilots are taught to use the standby attitude instruments but there is absolutely no training to pilots that indicates that the attitude indicators may stop displaying information as a matter of doing what they are designed to do.

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[8] Attachment 1 to Operational Factors Group Chairman's Factual Report, DCA01MA031: Interviews, C. Berry, pg. 13

[9] *Ibid., C. Berry, pg. 13*
[10] *Ibid., D. Myers, pg. 16*
[11] *Ibid., D. Myers, pg. 17*
[12] *Ibid., L. Lyons, pg. 19*
[13] *Ibid., K. Stamper, pg. 20*

Recommendations

2. The product manufacturer, Collins, should communicate the product limitations to the aircraft operator, and the operator should communicate those limitations to the end users, the pilots.

3. Further, the product manufacturer, Rockwell Collins, should redesign their product, the AHRS EADI system, to provide useful information without any disruption/discontinuity of its attitude display. The attitude information provided by the EADI should continue to display when a monitor exceedance occurs, though it may lag actual aircraft attitude. It should display continuously and resynchronize with actual aircraft attitude upon the roll rate exceedance no longer existing.

Trim in Motion

Prior to the event, the autopilot was engaged, as is normal for the cruise phase of flight. The autopilot then began to trim the elevator trim tab almost continuously for the last 2:40 (160 seconds) prior to the upset. There was no aural alert to the crew of trim in motion. The crew stated that there were high column forces after disconnect. Increasing engine power requires even greater column force to compensate for the engine thrust.

System Description – EMB-120 Brasilia Operations Manual
"Roll and pitch trimming is accomplished by the aileron and elevator tabs, actuated by irreversible mechanical actuators installed inside each aerodynamic surface." (pg. 6-8-12, 15 October 1990) The elevator trim range is from 2 units Aircraft Nose Down (AND) to 10 units Aircraft Nose Up (ANU).

The factual report for the Operational Factors Group contained a "Summary of EMB-120 Simulator Demonstration." The simulator was run with similar environmental conditions (airspeed, altitude, etc.) and then heavy icing was introduced. The factual report states: "It took about four minutes for the simulator to slow from 180 knots to 140 knots . . . as the airspeed was slowing from 180 knots to 140 knots, rudder input could be felt as the airspeed changed and the pitch change was significant and noticeable to the pilot. The pitch change was evident on the horizon indicator and was felt by the pilot." It should be noted that this simulator was only a simple reenactment, and not able to truly re-create the environmental conditions experienced during the actual event. The actual flight was experiencing substantial turbulence at the time that the trim was being entered, over the last few minutes, as shown in the vertical G FDR shown in Figure 3. This would have severely degraded the ability of the crew to detect the change in pitch attitude and the airspeed degradation.

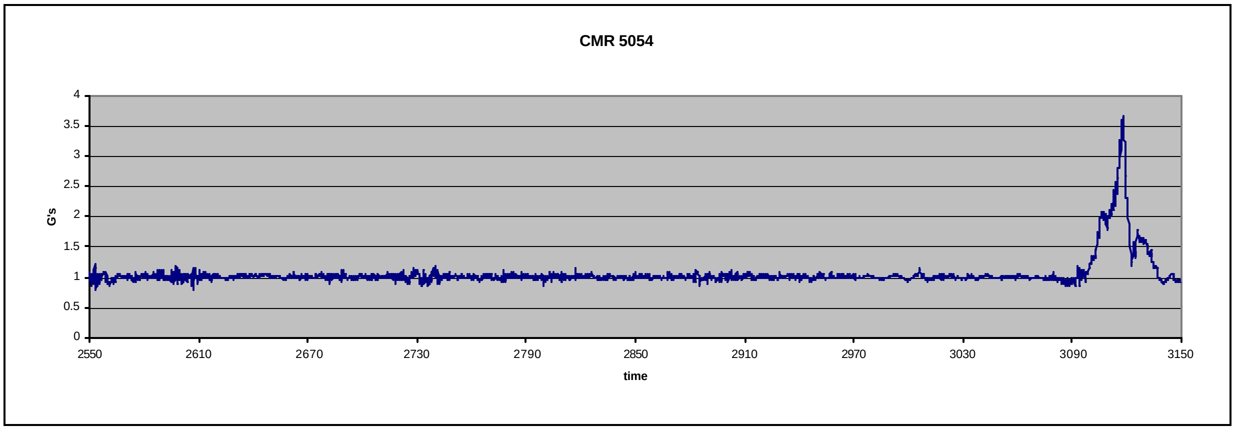

Figure 3

The autopilot flight control panel is provided with a number of mode annunciator indicators on the glareshield. This is enlarged in embedded steps in the following diagram, Figure 4. This alert is too small to be noticed and fails to be effective unless it is under continuous observation.

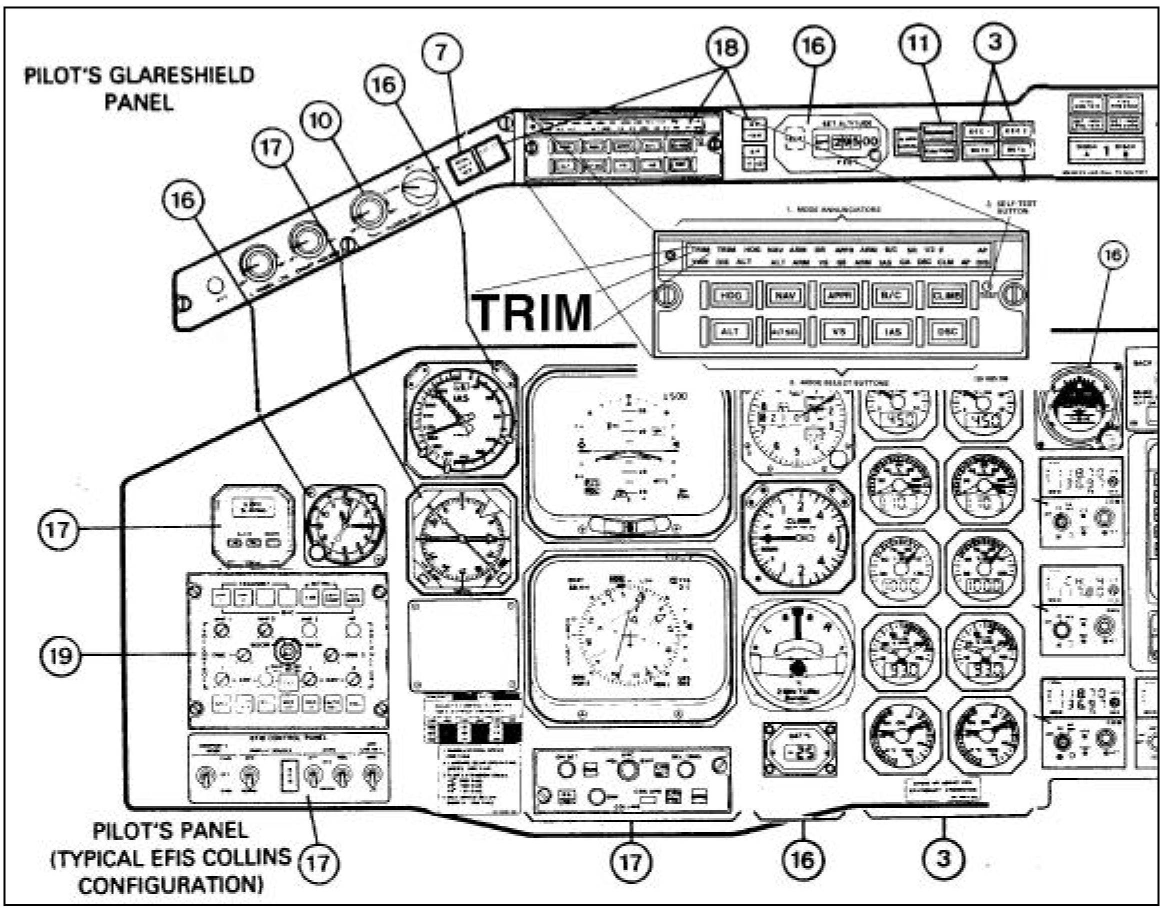

Figure 4

Figure 4 shows that the annunciator light provided for elevator trim in motion is not an adequate alerting indicator unless the crew already has their attention focused on this panel. The "TRIM" annunciator is in white, and illuminates to indicate that the trim system is in motion.

According to the report "Aircraft Alerting Systems Standardization Study, Volume II, Aircraft Alerting Systems Design Guidelines[14]", the master visual alerts should subtend at least 1 square degree of visual angle. At 30 inches from the eye, this is approximately 0.5 inches. In the EMB-120, the word "TRIM" is only approximately ¼ inches high on the autopilot mode annunciator panel. Brightness was also noted as a factor. The report stated regarding response time as a function of warning light size that: "The increases in mean response time and standard deviations for decreasingly small signal lights was largely ascribed to a tendency for the smaller signal lights to occasionally go undetected for extended periods of time." The noted report also provided guidance that: "An effective alerting [tone] system . . . should precede all visual and verbal alert messages with a master aural alert."[15]

Conclusions

The airplane was on autopilot, which trimmed the elevator trim tab in order to attempt to maintain the selected flight level cruising altitude. The crew did not notice the trim in motion due to their attention being focused on other activities in the cockpit and environmental influences that overshadowed the effect of the trim on airplane attitude and airspeed. The trim reached a high value of nose up trim which caused the airplane to be very difficult to control upon the autopilot being disengaged.

Recommendation

4. The manufacturer should develop a modification to the aircraft warning systems to make an aural alarm to indicate that the horizontal trim is in motion.

Stall Warning System Augmentation for Icing Conditions

The EMB-120 stall warning system should be biased when the airplane is in icing conditions to account for the airplane's change in stall characteristics when exposed to icing contamination on the wing.

The EMB-120 stall warning system consists of a stick shaker and stick pusher which are set to activate at 10.5? and 12.2? respectively. They are intended to maintain a high margin of safety from approaching the AOA where controllability problems were experienced during certification tests.

The stall warning system is intended to prevent the aircraft from operating at an AOA where it has been shown to perform in a manner that is unacceptable (controllability problems). In this case, it was shown in the early proving tests for the EMB-120 that on a clean wing the airplane had a tendency to roll rapidly to the left at approximately 18? AOA. Test pilots described high roll rates and uncontrollable roll-offs.

Stall warning systems are important since they are required only when the airplane shows a pattern of uncontrollability in roll as the airplane approaches the stall AOA. The FAA rules and guidance for stall behavior design considerations are thoroughly addressed in the ALPA submission regarding Comair flight 3272 (pg. 11). The guidance of AC 25-7, Flight Test Guide for Transport Category Airplanes, specifies, "For level wing stalls, the roll occurring between the

[14] DOT/FAA/RD-81/38,11 - January 1981
[15] Ibid, Vol. II, pg. 90

stall and the completion of the recovery may not exceed approximately 20 degrees." The airplane manufacturer can use a variety of methods to achieve this goal, including wing washout, aerodynamic devices (such as fences), and airfoil changes (short chord, sharp leading edges accrete ice more readily than wings with larger chords and more blunt leading edges). In this case, the manufacturer has chosen to not utilize washout (the entire wing has the same 2? angle of incidence). The AC 25-7 identifies that the manufacturer can choose to install a "stall identification device that is a strong and effective deterrent to further speed reduction."

The need for requiring a stall warning system to be biased downward for icing conditions was identified in the aftermath of the Simmons flight 4172 accident in Roselawn, IL, involving an ATR-72. In 1998, in the ALPA submission to the Board regarding Comair 3272, it was noted, "ALPA is participating in ARAC working groups that are considering changes to Part 25 that would require stall warning/identification systems to be rescheduled in icing conditions."

ALPA noted in our submission to CMR 3272 that: "The EMB-120 stick shaker and stick pusher activation [Angle of Attacks] AOA's are at 10.5? and 12.2? respectively. Both of these thresholds are based on a dry, uncontaminated wing. There is no allowance made for ice contamination of any degree." This continues to be the case, that Embraer has not corrected the problem of stall AOA needing decrementing for flight in icing conditions. The AOA for this event proceeded as shown in the following chart of Figure 5.

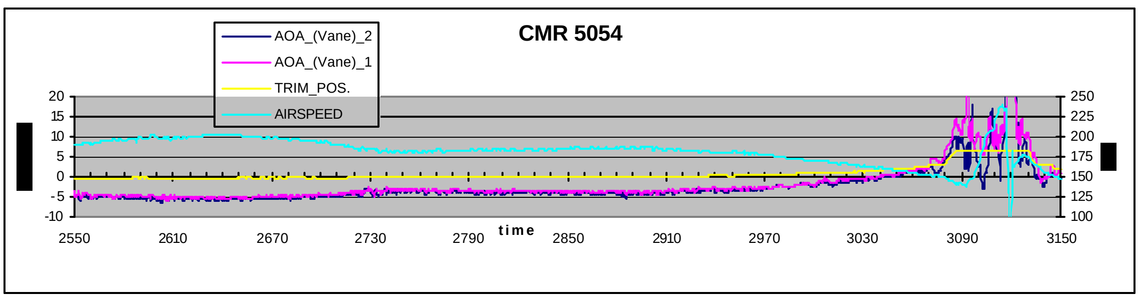

Figure 5

The graph in Figure 5 clearly shows that the AOA reached just 10 degrees as the trim reached a limit. Similarly, the Performance Group factual report documents the degradation in the lift coefficient to under 10% of the nominal lift coefficient (as a function of AOA), as the angle of attack (AOA) increases past 5?.

The factual report of the Performance Group contains graphs that clearly show the lift coefficient degrades with ice accretion (see figure 3 of the Performance Group Factual Report, Figure 6 below). This graph shows that the lift coefficient for the uncontaminated wing had a regular relationship increasing as the angle of attack increased, however for the contaminated wing, based on the actual flight data, the lift coefficient increased proportional to the AOA at only 9.5% of the rate of increase experienced below 5? AOA.

According to the NTSB accident report[16] for the Simmons Flight 4184 accident, the ATR-72 Stall Protection System (SPS) includes in its logic evaluation of the Angle of Attack (AOA), flap position, engine torque, on-ground/in-flight status, altitude above or below 500 feet above

[16] Pg. 23, NTSB/AAR-96/01

ground, and the presence or absence of optional deicers on the inner leading edges. The EMB-120 involved in the subject accident had a SPS logic that functioned only as dependent on the AOA.

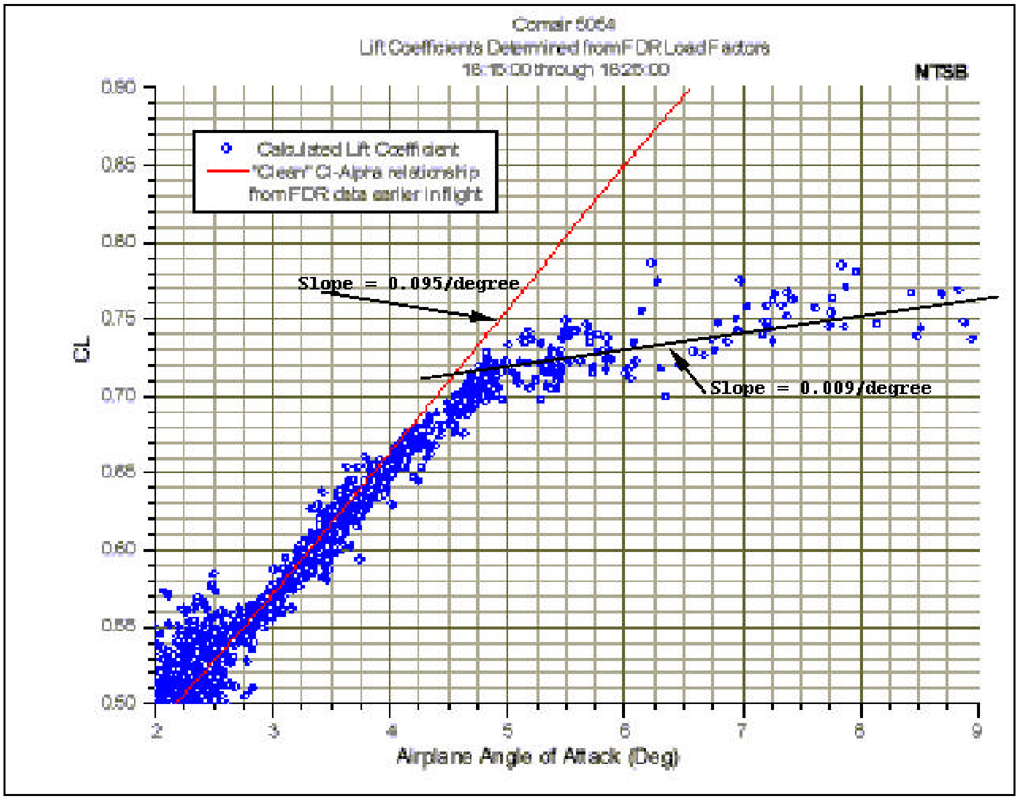

Figure 6

This degradation of the lift coefficient resulted in a significantly degraded aircraft performance. Such a characteristic resulted in the airplane rapidly losing speed as the autopilot trimmed the elevator trim tab in an attempt to achieve a higher lift coefficient in order to maintain altitude.

The First Officer reported in his Operations Group interview that: "He said he remembered hearing the clacker and the stick shaker at some point. The clacker and shaker were part of the stall warning system. After he heard the stall warning, he felt the airplane stall."[17] This suggests that the stall warning system was indeed operating, however, it no longer had a sufficient margin between the AOA for the warning and the AOA at which the stall and associated poor lateral controllability were known to occur.

The Board issued NTSB recommendation A-98-96 as a result of the Comair 3272 accident. That recommendation stated:
A-98-96 "Require the manufacturers and operators of all airplanes that are certificated to operate in icing conditions to install stall warning/protection systems that provide a cockpit warning (aural warning and/or stick shaker) before the onset of stall when the airplane is operating in icing conditions."

[17] Operations Factual Report, Attachment 1, pg. 4

The latest status for this recommendation is that this recommendation will be implemented retroactively to aircraft already certificated, though the rulemaking noted in the FAA reply (dated 9/21/01) has yet to appear.

Conclusions

The airplane experienced icing conditions that caused the autopilot to automatically trim the elevator in an Aircraft Nose Up direction, increasing the Angle of Attack. The wing stalled as the Angle of Attack was increased. The stall warning system did not engage at an Angle of Attack low enough to provide a reasonable margin of safety to prevent the wing from stalling.

Recommendation

5. The manufacturer should modify the logic in the stall warning system for the EMB-120 to decrement the angle of attack at which the stall warning system activates the stick pusher so that the airplane cannot approach the stalled condition when in icing environmental conditions.

<u>Training</u>

Training In Unusual Attitude Training

It is essential that training provide crewmembers with realistic information on the aircraft operation. In this accident, it became apparent that the simulator training on the EADI performance portrayed the EADI as imperturbable, whereas in fact, the EADI was designed with hard limits for its accuracy and ability to continue to function. This fidelity limit is documented in the Systems section.

The interviews noted in detail in the Systems section of this submission clearly indicate that the EADI training is not consistent with the actual operational design of the EADI. This may be due to the airline not providing such information to the training department, or that the airline was not provided this information by the EADI manufacturer, Rockwell Collins.

Conclusions

The accident airplane experienced roll rates in excess of those for which the EADI was designed. The training provided to the crew by the company did not reflect that the EADI would blank out upon the roll or pitch rates being exceeded.

Recommendation

6. The training program at all air carriers operating this type of EADI should be revised to reflect that the EADI may blank out if its roll or pitch rate limits are exceeded.

7. Training should also include direction to check the control surface trim positions immediately upon disconnecting the autopilot either intentionally or as a result of the autopilot reaching its authority limits.

Weather

Icing in tropic regions

There is research and information on icing in northern climates but nearly nothing on icing at higher altitudes as the subject flight experienced. The characterization of the flight environment experienced may be relevant to the definitions used in the Part 25 Appendix C icing envelope.

The prior flight leg for this accident had involved icing and conditions conducive to icing are common in the subtropic regions, yet there are few events involving aircraft icing in this region. The prior accidents and incidents involving icing of the EMB-120 are listed in the following Table 3.

EVENT	DATE	Latitude	ICE PROTECTION ACTIVATED?	ICE AMOUNT OBSERVED	AIRSPEED (KTS)	NOTES
Klamath Falls, OR	June 1989	42?9’	No?	Light	180 -> 160	?? Rapid speed decrease ?? Max power applied ?? Stick shaker as speed increasing ?? +/- 30° rolls
Fort Smith, TX	Sept. 1991	32?00’	No	Insignificant	?	?? Floor vibrations prior to upset ?? Right bank excursion
Clermont, France	Nov. 1991	45?47’	Yes	None	150	?? A/S decreased to 150 kts ?? 60° rolls
Pine Bluff, AR	April 1993	34?18’	No?	None	?	?? Autopilot on ?? No ice observed ?? 90° rolls
Elko, NV	October 1994	40?50’	No	Insignificant	150	?? Autopilot on ?? A/C in turn ?? A/C response unexpected ?? 90° roll
Tallahassee, FL	April 1995	30° 23’	Yes	Trace	180 -> 140	?? No upset ?? Airspeed decrease ?? Pitch increase
Monroe, MI (Comair 3272)	January 1997	32?31’	No?	Unknown	150	?? A/C exiting turn ?? Autopilot on ?? Autopilot unable to maintain bank angle ?? Excessive bank disconnected A/P ?? A/S decreased to 146 kts
Sacramento, CA (WestAir 7233)	March 1998	38° 31’	Yes	Light	147 (fdr)	?? Climbed to exit icing conditions ?? A/C exiting turn ?? Crew “felt” rumble prior to upset ?? Crew disengaged A/P

Table 3

Definition – Subtropics = of, relating to, or being the regions bordering on the tropical zone. Definition: Tropical zone = the region lying between the parallels of latitude known as the tropic of Cancer and the tropic or Capricorn, at 23.5? above and below the equator. As is evident from this tabulation and the definition of “subtropics”, these other accidents were *not* in subtropics. The subject accident was at a latitude of 26?41’. NCAR states that little research has been done in subtropics for icing. A search of the World Wide Web identified one experimental source for icing predictions by altitude in a graphical format. The following is a sample output from this resource (note the date is 3/18/02 (almost exactly 1 year after the accident flight, weather for this graphic is similar coincidentally to weather on date of the accident).

Table 3 shows that none of the accidents or incidents on record occurred in subtropic regions. Yet the prior flight leg showed icing and the following chart from an advanced icing research facility showed icing in southern regions, though by coincidence, not as far south as the subject accident.

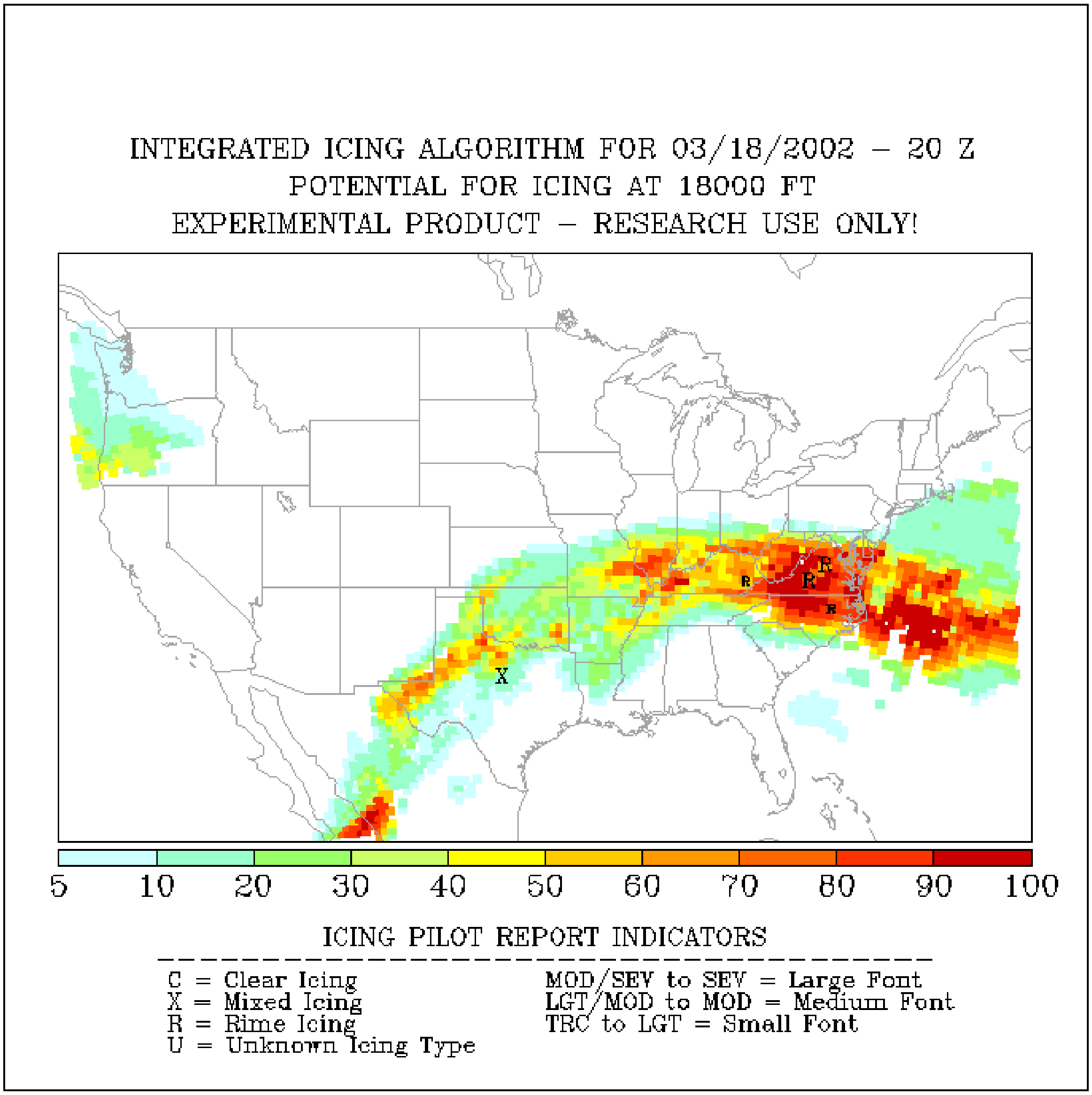

Figure 7

How the integrated icing algorithm pulls it all together[18]

The idea behind the integrated icing diagnostic is to take advantage of the abilities and minimize the shortcomings of both the model-based and instrument-based approaches, to try to capture the maximum number of PIREPs while impacting the smallest amount of area/volume possible. In general, the algorithm first integrates information from the GOES-8 satellite, surface observations and RUC model to identify the three-dimensional extent of cloud, then uses information from these resources plus the national radar mosaic to identify the locations and likelihood of both conventional and supercooled large drop (SLD) icing across the United States and Canada. A situational approach is used which applies

[18] http://www.rap.ucar.edu/largedrop/integrated/concept.txt

information from the different data sources in different ways, depending upon the physics expected to be at work at each location within the domain.
The integrated algorithm uses information from all four data sources (satellite, surface observations, radar mosaic, RUC model). By using information from several of them in a situational approach, it is possible to minimize the impact of bad data in any one field.

Comair as well as the majority of other air carriers have no graphic presentation of weather conditions provided to the crews in real time, or on the dispatch release. Passengers have better weather capabilities from their laptop PC hookups than the flight crew.

Conclusions

The accident airplane was in a weather environment conducive to icing and certificated as being able to operate in such conditions. The airplane was unable to maintain safe flight, thus the weather conditions experienced must have been in excess of those for which the airplane was demonstrated to safely function. The resulting loss of control put the airplane and occupants at risk unnecessarily.

Recommendations

8. Further research and development is needed regarding forecasting and prediction of icing in subtropical regions.

9. Systems and methods should be developed to enhance a crew's ability to detect and avoid icing conditions that exceed the demonstrated capability of the airplane.

10. Flight crews should be provided real time weather charts with detailed icing information included.

<u>Performance</u>

EMB-120 Ice Accretion Characteristics

The evidence from this accident shows a severe performance degradation due to the ice accretion experienced. Since the hazard of entering this type of ice environment is so severe, it is imperative that there be a definitive system for alerting the flight crew of operating the airplane in conditions beyond for which the airplane is certificated. It is not sufficient for the crews to be trained to be able to observe icing conditions outside those defined in 14 CFR Part 25, Appendix C.

It is ineffective to provide graphical depictions of ice accretions on the windshield, the windshield wiper, or the spinner and to be directed that any ice accretion of greater extent than that in the graphical depiction is outside of the approved flight envelope. There is a real possibility that crews may be paired up that together have little experience in observing ice accretion characteristics that indicate the environmental conditions are outside of the limits of Appendix C of Part 25.

Past accidents, as noted above in the Weather section, and this accident, make it clear that there are insufficient systems in place to advise the crew of when they are in environmental conditions exceeding those for which the airplane is authorized to operate.

During the CMR 3272 investigation an FAA icing specialist stated that the EMB-120 may be one of several models of airplanes that have unusual icing characteristics needing special certification examination. There appears to be a need to ensure that the EMB-120 does not have aircraft performance and handling qualities within the current Part 25 Appendix C envelope that excessively impair the aircraft handling. This was raised as an issue in the Comair 3272 investigation and has yet to be resolved.

Embraer acknowledged in their submission to the Board for CMR 3272[19] that the airplane can accumulate ice on its wings aft of the boots and that this would decrease the lift coefficient and increase the drag coefficient of the airplane.

It was noted in the ALPA submission to CMR 3272 that BFGoodrich conducted an icing impingement study for the EMB-120 airfoils to determine the necessary extent of the deicing boot coverage. The study concluded that the boots as they existed then and currently exist did not provide complete ice protection when exposed to 14 CFR Part 25, Appendix C icing conditions.

The FAA's Aviation Rulemaking Advisory Committee (ARAC) Harmonization Issues Group formed a working group in response to recommendations for reexamining the icing envelope and qualification tests. The ARAC group proposed redefining the icing envelope into separate conditions for different phases of flight (takeoff, holding, etc.), however, these have not been incorporated into the regulations, nor has there been any action to reexamine the adequacy of the original design of the wing and deicing system for the EMB-120.

EMB-120 Aircraft Design – De-icer boots

The EMB-120 deicing system consists of pneumatically-inflated rubber boots, installed over the tail and wing leading edge surfaces, as well as the engine air inlet lips and engine air bypass duct. The dimensions and coverage of the boots are critical in assuring adequate deicing in operation. The typical average wing de-icing boot limits for the EMB-120 are: upper = 4.4 inches chord, lower = 7.4 inches chord, at 68 inches full wing chord, representative of the wing from span 5880 to 7680 mm (encompassing a region in front of the outboard flap panel and the aileron root). This equates to 6.5% and 11% boot coverage, upper and lower, respectively.

A NASA study of ice accretion on the NACA 23012 (similar in size and characteristics to that on the EMB-120) showed that "an ice ridge formed aft of the active portion of the deicer boot for every experimental test run in which ice was accreted. The location, height, and spanwise extent of the ridge varied considerably. This variability was caused by random shedding of the ice."[20] The NASA study as well as the BFGoodrich study showed that aft impingements of ice resulted in significant increases of drag on the airfoil. Such increases in drag directly affect the aircraft performance and, as is evident in the numerous accidents and incidents involving the EMB-120, cause aircraft control and handling problems that put the safety of flight at serious risk. These studies appear sufficient in themselves to support redesign of the EMB-120 deicing boots. The ARAC redefinition of the icing envelope will only further identify that the deicing boots of the EMB-120 are inadequate.

[19] Embraer, Submission of Embraer to the National Transportation Safety Board Regarding the Comair Flight 3272 Accident at Monroe, Michigan on January 9, 1007, DCA-97-MA-017, pg. 46

[20] NASA Technical Memorandum 107424, "A Study of Large Droplet Ice Accretion in the NASA Lewis IRT at Near-Freezing Conditions; Part 2", H. E. Addy, Jr, D.R. Miller, R.F. Ide

The NASA testing showed that operation of the boots did not significantly reduce the drag. This was in the Icing Research Tunnel for 5 minutes in Appendix C Part 25 conditions. It is possible that increasing the boot size on the wing still would not prevent such drag increases. Thus, this leads to the need for a system to detect when ice is accreting in excess of the capability of the boots to shed the ice.

Conclusions

The EMB-120 wing is susceptible to ice accretion beyond that area protected by the deicing boots. Ice accretion on the EMB-120 caused degraded flight performance and resulted in the airplane's loss of control. Research indicates that corrective action by increasing boot size may not be feasible. In the event a redesign of the boots could not feasibly prevent ice impingement accretions, there is a need for a system to alert crews when such environmental conditions that cause ice impingement are being entered.

Recommendation

11. The deicing boots of the EMB-120 should be redesigned by increasing their coverage area to ensure that they can maintain the wing free of ice.

12. The manufacturer should develop a system to alert the crew when the ice protection system is not effectively protecting the airplane from ice accretion that results in the increase of drag during the icing encounter.

Weight and Balance

The aircraft was nearly full with 25 passengers (21 adults and 4 children). The documented flight release[21] showed a payload of 4400 lbs, and a takeoff weight of 25,138 lbs. The Load Manifest completed by the crew showed the payload as 4,520 lbs, 120 lbs more than the computer generated flight departure papers. The crew completed their load manifest manually computing the values entered, using standard weights for the passengers (175 lbs, 80 lbs per child) and bags (21 bags at 25 lbs each).

The investigation of this issue was hampered by not documenting the actual bag or passenger weights. It was reported that the airplane was impounded for the investigation initially after the airplane landed, but then the bags were released. The baggage compartment is at the rear of the airplane and as this location is at a relatively large distance from the wing, it affects the airplane center of gravity calculation significantly. It is unfortunate that no factual information was collected for the actual airplane and payload weights, as this could significantly affect the airplane performance.

Historically, anecdotal information suggests that on international flights the bag weights average twice the value used in the official weight and balance form used by the flight crew. There was no documentation performed in the investigation of the method in which the airline determined that the current standard weights used are indeed appropriate.

[21] Operations Group factual report, Attachment 3 Flight 5054 Flight Departure Papers

The FAA held an Aviation Rulemaking Advisory Committee (ARAC) working group on the issue of passenger and baggage weight in 1992. Numerous references to passenger and bag weight surveys were documented. The ARAC work resulted in development of the Advisory Circular (AC) 120-27c, published in 1995. This AC specified detailed methods on how to perform a passenger and bag survey, as well as increased values for the standard passenger and bag weights (180/185 lbs (summer/winter), including 20 lbs per passenger for carry-on bags) however, the FAA does not require an airline to use these values or to periodically perform weight surveys.

The effect of higher passenger and bag weights on airplane performance is to alter airspeed and the Angle of Attack (AOA) needed to achieve equilibrium of lift and drag. Further, differences in the weight distribution due to cargo compartment weight differences affects the trim and power settings and can invalidate the analysis done as part of the performance documentation.

Conclusions

The airplane was dispatched at a computed weight just under the maximum allowed takeoff weight. Standard passenger and bag weights were used that have not been validated for the route flown. Experience shows that actual bag weights are often much more than the standard bag weight. Airplane performance is significantly affected by changes in passenger and bag weights.

Recommendation

13. The FAA should require airlines to conduct periodic passenger and bag weight surveys that are specific to the routes flown.

Outstanding Issues from CMR 3272

ALPA Recommendations

ALPA made numerous recommendations as part of the submission to the investigation of Comair 3272. The full listing is included in Appendix A. The following items are noteworthy for their significance.

The prior recommendations by ALPA were focused on the airplane design and its characteristic behavior in icing conditions and preventing that from degrading the performance to the point where the airplane was not able to fly under control The recommendations addressed redesign of the wing deicing system and establishing alerts for the autopilot system taking action in response to the icing conditions, without the crew awareness. Our bottom line recommendation, for the autopilot to not be used in icing conditions, was adopted as recommendation A-98-101, but not yet implemented. The FAA letters on this recommendation are not specific enough on whether this part of the recommendation will be implemented. This action may have yet resulted in the airplane loss of control, however, it probably would have been in a less extreme change of airplane attitudes.

It remains important to improve the ability to determine whether the icing conditions being experienced by an airplane are in excess of those for which the airplane has been demonstrated. There has been no effective action in this regard. Nor has there been a clear confirmation that the EMB-120 was adequately evaluated for its completely meeting the regulations of 14 CFR Part 25, since this airplane was approved for service in the U.S. by a Bilateral Airworthiness Agreement.

NTSB Recommendations

The NTSB recommendations issued following Comair 3272 are included in Appendix B, with comments on the ALPA perspective regarding the status of each recommendation. It is our view that the FAA action in response to these recommendations has been particularly slow, with far too much inertia holding to the status quo, when it has been clearly shown by the numerous icing events involving the EMB-120 that this airplane needs to be reevaluated for its adequacy in performance and handling in icing conditions. It is imperative that the FAA follow up on the NTSB recommendations and ensure that the EMB-120 meets the requirements of 14 CFR Part 25.

Recommendations

1. We urge the Board to examine all accidents of airplanes involving inflight loss of control and the ensuing aircraft dynamics to determine the appropriate possible roll and pitch rates that may be experienced, and to provide that data to the SAE A-4 Aircraft Instruments Committee for updating the AS 8001.

2. The product manufacturer, Collins, should communicate the product limitations to the aircraft operator, and the operator should communicate those limitations to the end users, the pilots.

3. Further, the product manufacturer, Rockwell Collins, should redesign their product, the AHRS EADI system, to provide useful information without any disruption/discontinuity of its attitude display. The attitude information provided by the EADI should continue to display when a monitor exceedance occurs, though it may lag actual aircraft attitude. It should display continuously and resynchronize with actual aircraft attitude upon the roll rate exceedance no longer existing.

4. The manufacturer should develop a modification to the aircraft warning systems to make an aural alarm to indicate that the horizontal trim is in motion.

5. The manufacturer should modify the logic in the stall warning system for the EMB-120 to decrement the angle of attack at which the stall warning system activates the stick pusher so that the airplane cannot approach the stalled condition when in icing environmental conditions.

6. The training program at all air carriers operating this type of EADI should be revised to reflect that the EADI may blank out if its roll or pitch rate limits are exceeded.

7. Training should also include direction to check the control surface trim positions immediately upon disconnecting the autopilot either intentionally or as a result of the autopilot reaching its authority limits.

8. Further research and development is needed regarding forecasting and prediction of icing in subtropical regions.

9. Systems and methods should be developed to enhance a crew's ability to detect and avoid icing conditions that exceed the demonstrated capability of the airplane.

10. Flight crews should be provided real time weather charts with detailed icing information included.

11. The deicing boots of the EMB-120 should be redesigned by increasing their coverage area to ensure that they can maintain the wing free of ice.

12. The manufacturer should develop a system to alert the crew when the ice protection system is not effectively protecting the airplane from ice accretion that results in the increase of drag during the icing encounter.

13. The FAA should require airlines to conduct periodic passenger and bag weight surveys that are specific to the routes flown.

In Closing . . .

It seems clear that the remedies implemented after the accident of Comair 3272 have not been effective in preventing icing related upsets specifically related to the EMB-120. It is imperative that further investigation be done and design changes to the aircraft type be accomplished to preclude any additional icing related occurrences that may not end as fortunately. We urge you to make recommendations to achieve this goal. Thank you for ensuring that these items get thoroughly addressed.

Appendix A – ALPA Recommendations from CMR 3272 Investigation

No.	Recommendation	Comment
1.	The Federal Aviation Regulations (FARs) should include guidance for the testing and assessment of aircraft handling qualities in icing conditions.	The guidance has been developed in AC 25.1419-1 - Certification Of Transport Category Airplanes For Flight In Icing Conditions, dated 8/18/99.
2.	Recommend that all training syllabuses be modified to include aircraft specific handling characteristics in icing conditions as a required item.	ALPA finds that the training continues to be inadequate regarding handling characteristics in icing conditions.
3.	The FAA must continue its inflight icing research on all aircraft with the intent of further characterizing the icing-environment, providing concise methods for flightcrews to identify the environment they are operating.	The research performed is good, but further research needs to be done, including examining handling and performance, as well as icing in the subtropics.
4.	For the EMB-120 and all aircraft with pneumatic de-icing systems and manual controls, revise the Operating Procedures to ensure that flightcrews disengage the autopilot if the aircraft is encountering icing conditions.	This recommendation was adopted by the NTSB (A-98-97, Closed, Unacceptable Action) but was not successfully implemented.
5.	For the EMB-120 and all aircraft with pneumatic de-icing systems and manual controls, revise the Operating Procedures to ensure that, at the first sign of weather conditions conducive to ice formation, all ice protection systems be turned on and remain on until exiting icing conditions.	This recommendation was adopted by the NTSB (A-98-90) and implemented, however, it alone is not adequate in preventing future icing accidents.
6.	Revise FAR 121 to ensure that aircraft certificated with ice protection systems have system status information recorded on the Flight Data Recorder.	This recommendation was not adopted by the NTSB and was noted as an issue causing uncertainty during this investigation.
7.	Revise FAR 121 to ensure that aircraft power lever angle information is recorded on the Flight Data Recorder.	This recommendation was adopted in spirit by the NTSB recommendation A-95-27 and implemented in FAR 121.344.

Appendix A - ALPA Recommendations from CMR 3272 Investigation

8.	For aircraft that are not so-equipped, aircraft ice/rain protection systems which are equipped with an automatic feature should be required to complete an entire cycle when selected OFF.	This recommendation was not adopted, nor does the AC 25-1419-1 adequately address this issue.
9.	For aircraft that are certificated under FAR Part 25 and are not so-equipped, require that their stall warning system activation angles be biased based upon ice protection system status. Essentially the same stall warning and identification margins that were intended in the uncontaminated condition should remain valid with ice accretions resulting from Appendix C icing conditions. This requirement should be retroactive to cover all aircraft engaged in air carrier operations.	This recommendation was adopted in NTSB as A-98-96, which has a status of Open, Acceptable Response, but it has yet to be implemented.
10.	Ensure that the EMB-120 aircraft meets all applicable requirements of FAR 25.	There is no indication that this has been accomplished.
11.	For the EMB-120 and those aircraft that are not so-equipped, install an "aural" trim-in-motion system.	The manufacturer has indicated that this can be accomplished, however, no recommendation has been issued.
12.	All operators of the EMB-120 should revise their training syllabus to ensure that the use of the fast/slow indicator is taught. It should be stressed to flightcrews that the fast/slow indicator is an additional tool to be used to safely operate the aircraft.	The use of the fast/slow indicator is not emphasized as a tool for cruise, nor in icing.
13.	Recommend to Embraer that the fast slow indicator be calibrated and certified for $1.3V_S$ at all possible aircraft configurations.	This recommendation was not adopted or implemented. ALPA continues to believe that such a calibration is needed.
14.	Autopilot certification standards should be reviewed and changed where necessary to require warning systems to alert the flightcrew in advance of an autopilot disconnect.	It appears that no recommendation was made adopting this. It remains an issue of high importance.
15.	On the EMB-120 or aircraft that are not so-equipped, provide flightcrews with a "bank angle" warning with a triggering threshold beyond a standard rate turn but well in advance of autopilot disconnect due to excessive bank angle.	It appears that NTSB recommendation A-92-35 comes close to addressing this, but does not succeed in making a warning for the autopilot at excessive bank angles.

16.	Ice detector systems should have the capability to detect and notify the flightcrew of an encounter with FAR 25, Appendix C icing conditions and conditions beyond FAR 25, Appendix C. The system should have the ability to differentiate between those conditions and properly enunciate it to the flightcrew.	The NTSB recommendation A-97-34 addresses only alerting for ice detection. There should be a recommendation for development of a detection system that will alarm as outlined here.
17.	Require operators to provide clear definitions to their flightcrews as to how company bulletin information should be incorporated and utilized.	This was adequately adopted in intent by NTSB recommendation A-98-89.
18.	For the EMB-120, and those aircraft not so-equipped, minimum maneuvering speeds for every aircraft configuration should be generated and provided to all flightcrews.	NTSB recommendation A-98-94 addressed this, however, it noted that there needs to be specific information for operations in icing conditions.
19.	Ice protection system manufacturers should determine the proper operation of their system. They should make that information available to all manufacturers that utilize their system and all operators for incorporation into their procedural manuals.	There continues to be insufficient information from ice protection system manufacturers for how to best operate their equipment.
20.	Ensure that all pertinent aircraft incident information be compiled and disseminated to the operators of their specific equipment and distributed to the appropriate flightcrews.	Flight crews continue to believe that insufficient incident information is disseminated for their reference.
21.	FAA should develop a formal method to determine if manufacturer Operations Bulletin information requires regulatory action.	NTSB recommendation A-98-103 was closed with acceptable action implementing this recommendation.
22.	The FAA should develop a formal method to ensure that all manufacturer Operations Bulletin information is distributed to the appropriate operators and flightcrews.	NTSB recommendation A98-89 adopted this recommendation. Its status is “Open Acceptable Response”.

23.	Require all air carrier pilots receive simulator training in both full stall recovery and ice induced roll upsets. Simulators should include contaminated airfoil handling qualities characteristics (e.g. ice induced roll upsets).	No NTSB recommendations were adopted to reflect this recommendation.
24.	The FAA should immediately initiate a review of the engineering and certification data used to substantiate the AFM procedures for operating the ice protection system on all aircraft used in air carrier operations. This review should insure that these procedures are substantiated by reliable, repeatable engineering data and that no significant degradations in aircraft safety margins exist at any time during the normal, approved operation of the ice protection system.	NTSB recommendation A-98-90 adopted this point, and its status is noted as “Closed Acceptable Action”.
25.	Review Aircraft Flight Manuals and company standards manuals to ensure that flight critical procedures are consistent between documents and are included in the appropriate procedural sections (i.e. Emergency, Abnormal, Normal, etc.).	This recommendation was adopted in part in NTSB recommendation A-98-89. There remains no recommendation to ensure consistency between procedural sections.

Appendix B – NTSB Recommendations on CMR 3272

Rec Nbr	Subject	Status	Text	Comment
A-98-90	COMAIR-TRNG/HAZ/ICE COND	CLOSED ACCEPTABLE ACTION	A-98-90. With the National Aeronautics and Space Administration and other interested aviation organizations, organize and implement an industry-wide training effort to educate manufacturers, operators, and pilots of air carrier and general aviation turbopropeller-driven airplanes regarding the hazards of thin, possibly imperceptible, rough ice accumulations, the importance of activating the leading edge deicing boots as soon as the airplane enters icing conditions (for those airplanes in which ice bridging is not a concern), and the importance of maintaining minimum airspeeds in icing conditions.	Training continues to be marginal. There is insufficient information provided to the flight crew in training on the performance and handling characteristics of aircraft with ice accretions.
A-98-104	COMAIR	OPEN UNACCEPTABLE RESPONSE	A-98-104. Revise its current EMB-120 flight data recorder (FDR) system inspection procedure to include a FDR readout and evaluation of parameter values from normal operations to ensure a more accurate assessment of the operating status of the flight control position sensors on board the airplane.	ALPA concurs that the action taken is unacceptable. It is imperative to validate that the Flight Data Recorder is accurately recording data.
A-98-102	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-102. Require air carriers to adopt the operating procedures contained in the manufacturer's airplane flight manual and subsequent approved revisions or provide written justification that an equivalent safety level results from an alternative procedure.	

Appendix B - NTSB Recommendations on CMR 3272
Sorted by date of most recent letter

Rec Nbr	Subject	Status	Text	Comment
A-98-100	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-100. When the revised icing certification standards and criteria are complete, review the icing certification of all turbopropeller-driven airplanes that are currently certificated for operation in icing conditions and perform additional testing and take action as required to ensure that these airplanes fulfill the requirements of the revised icing certification standards.	The action taken in response to this recommendation should have been effective in preventing this accident, therefore, ALPA finds that this response has been unacceptably performed. The revised icing certification standards must be implemented and the changes to the Airplane Flight Manual made in order to make this recommendation effective.
A-98-96	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-96. Require the manufacturers and operators of all airplanes that are certificated to operate in icing conditions to install stall warning/protection systems that provide a cockpit warning (aural warning and/or stick shaker) before the onset of stall when the airplane is operating in icing conditions.	This recommendation also could have resulted in preventing the subject accident if it were already implemented. This recommendation should be made a high priority.
A-98-94	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-94. Require manufacturers of all turbine-engine driven airplanes (including the EMB-120) to provide minimum maneuvering airspeed information for all airplane configurations, phases, and conditions of flight (icing and non-icing conditions); minimum airspeeds also should take into consideration the effects of various types, amounts, and locations of ice accumulations, including thin amounts of very rough ice, ice accumulated in supercooled large droplet icing conditions, and tailplane icing.	This recommendation in itself was not effective in preventing the subject accident, due to the other recommendations listed here not being implemented yet, specifically regarding the stall warning system, and the airplane certification tests.

Appendix B - NTSB Recommendations on CMR 3272
Sorted by date of most recent letter

A-98-91	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-91. Require manufacturers and operators of modern turbopropeller-driven airplanes in which ice bridging is not a concern to review and revise the guidance contained in their manuals and training programs to include updated icing information and to emphasize that leading edge deicing boots should be activated as soon as the airplane enters icing conditions.	Implementing this recommendation would not have altered the outcome of this accident.
A-98-101	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-101. Review turbopropeller-driven airplane manufacturers' airplane flight manuals and air carrier flightcrew operating manuals (where applicable) to ensure that these manuals provide operational procedures for flight in icing conditions, including the activation of leading edge deicing boots, the use of increased airspeeds, and disengagement of autopilot systems before entering icing conditions (that is, when other anti-icing systems have traditionally been activated).	Implementing the action proposed in this recommendation probably would have prevented the subject accident, however, it should be recognized that the disengagement of the autopilot could cause problems in other ways regarding the safety of flight.
A-98-92	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-92. With the National Aeronautics and Space Administration and other interested aviation organizations, conduct additional research to identify realistic ice accumulations, to include intercycle and residual ice accumulations and ice accumulations on unprotected surfaces aft of the deicing boots, and to determine the effects and criticality of such ice accumulations; further, the information developed through such research should be incorporated into aircraft	ALPA recognizes that the action of this recommendation is under way and will positively effect many of the recommendations listed here.

			certification requirements and pilot training programs at all levels.	
A-98-98	COMAIR	OPEN UNACCEPTABLE RESPONSE	A-98-98. Require all manufacturers of transport-category airplanes to incorporate logic into all new and existing transport-category airplanes that have autopilots installed to provide a cockpit aural warning to alert pilots when the airplane's bank and/or pitch exceeds the autopilot's maximum bank and/or pitch command limits.	ALPA agrees that this recommendation has been unacceptably resolved. Implementing the intent of this recommendation could have lessened the effects of the event and may have prevented the loss of control.
A-98-93	COMAIR	CLOSED UNACCEPTABLE ACTION	A-98-93. Actively pursue research with airframe manufacturers and other industry personnel to develop effective ice detection/protection systems that will keep critical airplane surfaces free of ice; then require their installation on newly manufactured and in-service airplanes certificated for flight in icing conditions.	ALPA agrees that this recommendation has been unacceptably resolved. Implementing this recommendation may have prevented the loss of control and ensured the airplane continued to have adequate performance and handling.
A-98-97	COMAIR	CLOSED UNACCEPTABLE ACTION	A-98-97. Require all operators of turbopropeller-driven air carrier airplanes to require pilots to disengage the autopilot and fly the airplane manually when they activate the anti-ice systems.	ALPA agrees that this recommendation has been unacceptably resolved. However, this alone would not ensure the safety of the airplane, since the performance and handling may have been severely compromised, given the level of icing conditions experienced.
A-98-105	COMAIR	OPEN ACCEPTABLE RESPONSE	A-98-105. Reemphasize to pilots, on a periodic basis, their responsibility to report meteorological conditions that may adversely affect the safety of other flights, such as in-flight icing and turbulence, to the appropriate facility as soon as practicable.	ALPA agrees that pilots should be periodically given the message to pass on pilot reports of severe icing.

A-98-95	COMAIR	OPEN UNACCEPTABLE RESPONSE	A-98-95. Require the operators of all turbine-engine driven airplanes (including the EMB-120) to incorporate the manufacturer's minimum maneuvering airspeeds for various airplane configurations and phases and conditions of flight in their operating manuals and pilot training programs in a clear and concise manner, with emphasis on maintaining minimum safe airspeeds while operating in icing conditions.	ALPA concurs that the FAA response is inadequate, considering that the bulletins noted by the FAA do not address minimum safe maneuvering speeds for operating in icing conditions.
A-98-89	COMAIR-FLIGHT MAN REV	OPEN ACCEPTABLE RESPONSE	A-98-89. Require principal operations inspectors (POIs) to discuss the information contained in airplane flight manual revisions and/or manufacturers' operational bulletins with affected air carrier operators and, if the POI determines that the information contained in those publications is important information for flight operations, to encourage the affected air carrier operators to share that information with the pilots who are operating those airplanes.	
A-98-106	COMAIR	CLOSED RECONSIDERED	A-98-106. Amend Federal Aviation Administration Order 7110.65, "Air Traffic Control," to require that automatic terminal information service broadcasts include information regarding the existence of pilot reports of icing conditions in that airport terminal's environment (and adjacent airport terminal environments as meteorologically pertinent and operationally feasible) as soon as practicable after receipt of the pilot report.	

A-98-103	COMAIR	CLOSED ACCEPTABLE ACTION	A-98-103. Ensure that flight standards personnel at all levels (from aircraft evaluation groups to certificate management offices) are informed about all manufacturer operational bulletins and airplane flight manual revisions, including the background and justification for the revision.	
A-98-88	COMAIR-TRACE ICING	CLOSED ACCEPTABLE ACTION	A-98-88. Amend the definition of trace ice contained in Federal Aviation Administration (FAA) Order 7110.10L, "Flight Services," (and in other FAA documents as applicable) so that it does not indicate that trace icing is not hazardous.	
A-98-99	COMAIR	CLOSED RECONSIDERED	A-98-99. Expedite the research, development and implementation of revisions to the icing certification testing regulations to ensure that airplanes are adequately tested for the conditions in which they are certificated to operate; the research should include identification (and incorporation into icing certification requirements) of realistic ice shapes and their effects and criticality.	
A-97-31	COMAIR/ EMB120/ FLAPS	CLOSED ACCEPTABLE ACTION	A-97-31. Require air carriers to reflect FAA-approved minimum airspeeds for all flap settings and phases of flight, including flight in icing conditions, in their EMB-120 operating manuals.	Minimum airspeeds are not sufficient when aircraft performance can degrade so quickly upon exposure to icing conditions.

A-97-33	COMAIR/ EMB120/ TRAINING	CLOSED ACCEPTABLE ACTION	A-97-33. Direct Principal Operations Inspectors (POIs) to ensure that all EMB-120 operators provide flightcrews with training that emphasizes the recognition of icing conditions and the need to adhere to the procedure for using de-ice boots that is specified in the revised Embraer EMB-120 airplane flight manual.	
A-97-32	COMAIR/ EMB120/ TRNG	CLOSED ACCEPTABLE ACTION	A-97-32. Ensure that the de-icing information and procedures in air carriers' EMB-120 operating manuals and training programs are consistent with the revised Embraer EMB-120 airplane flight manual.	
A-97-34	COMAIR/ EMB120/ICE DETECTION	CLOSED ACCEPTABLE ACTION	A-97-34. Require that all EMB-120 aircraft be equipped with automated ice detection and crew alerting systems for detecting airframe ice accretion.	ALPA notes that while ice detection system are required, there still remains no system to detect and identify that an airplane is in icing conditions exceeding those for which it was demonstrated to perform.