3. CONCLUSIONS

3.1 Findings

1. The pilots were properly qualified and certificated to perform the flight during which the accident occurred, and each crewmember had received the training and off-duty time prescribed by the Federal regulations. There was no evidence of any preexisting medical or behavioral conditions that might have adversely affected the flightcrew's performance.

2. The airplane was certificated, equipped, and dispatched in accordance with Federal regulations and approved Comair procedures. There was no evidence of preexisting mechanical malfunction or other failure of the airplane structure, flight control or other systems, powerplants or propellers that would have contributed to the accident.

3. It is likely that the leading edge deicing system was capable of normal operation during the accident flight.

4. The Detroit terminal radar approach controllers who were involved with flight 3272 were properly qualified and certificated. A review of air traffic control and facility procedures revealed that the controllers followed applicable air traffic and wake turbulence separation rules, and air traffic separation was assured during flight 3272's approach to the runway.

5. Although the radar ground tracks of Cactus 50 and Comair flight 3272 converged near the accident site, the Safety Board's review of winds aloft and wake vortex sink rates indicated that Cactus 50's wake vortices would have been above and northeast of Comair flight 3272's flightpath near the upset location. Thus, Comair flight 3272 was separated from the vortices vertically and horizontally, and, therefore, wake turbulence was not a factor in the accident.

6. The airplane was aerodynamically clean, with no effective ice accreted, when it began its descent to the Detroit area.

7. The weather conditions near the accident site were highly variable and were conducive to the formation of rime or mixed ice at various altitudes and in various amounts, rates, and types of accumulation; if supercooled large droplet icing conditions were present, the droplet sizes probably did not exceed 400 microns and most likely existed near 4,000 feet mean sea level.

8. It is likely that Comair flight 3272 gradually accumulated a thin, rough glaze/mixed ice coverage on the leading edge deicing boot surfaces, possibly with ice ridge formation on the leading edge upper surface, as the airplane descended from 7,000 feet mean sea level (msl) to 4,000 feet msl in

icing conditions; further, this type of ice accretion might have been imperceptible to the pilots.

9. The suggestion in current Federal Aviation Administration publications that "trace" icing is "not hazardous" can mislead pilots and operators about the adverse effects of thin, rough ice accretions.

10. Because the pilots of Comair flight 3272 were operating the airplane with the autopilot engaged during a series of descents, right and left turns, power adjustments, and airspeed reductions, they might not have perceived the airplane's gradually deteriorating performance.

11. The accident airplane's left roll tendency was precipitated by a thin layer of rough ice that accumulated on the leading edge of the wing during the airplane's cruise descent, and was then affected by some or all of the following factors: the autopilot-commanded left roll, asymmetrical ice self-shedding, aileron deflection effects (localized airflow separations), the effects of engine/propeller thrust, the asymmetrical power application, and the disengagement of the autopilot. It is unlikely that the absence of conductive edge sealer on the left wing leading edge deicing boot segments was a factor in the airplane's excessive left roll.

12. Consistent with Comair's procedures regarding ice protection systems, the pilots did not activate the leading edge deicing boots during their descent and approach to the Detroit area, likely because they did not perceive that the airplane was accreting significant (if any) structural ice.

13. Had the pilots of Comair flight 3272 been aware of the specific airspeed, configuration, and icing circumstances of the six previous EMB-120 icing-related events and of the information contained in operational bulletin 120-002/96 and revision 43 to the EMB-120 airplane flight manual, it is possible that they would have operated the airplane more conservatively with regard to airspeed and flap configuration or activated the deicing boots when they knew they were in icing conditions.

14. The current operating procedures recommending that pilots wait until ice accumulates to an observable thickness before activating leading edge deicing boots results in unnecessary exposure to a significant risk for turbopropeller-driven airplane flight operations. Based primarily on concerns about ice bridging, pilots continue to use procedures and practices that increase the likelihood of (potentially hazardous) degraded airplane performance resulting from small amounts of rough ice accumulated on the leading edges.

15. It is possible that ice accretion on unprotected surfaces and intercycle ice accretions on protected surfaces can significantly and adversely affect the

aerodynamic performance of an airplane even when leading edge deicing boots are activated and operating normally.

16. Current ice detection/protection requirements and application of technology (particularly deice boots) may not provide adequate protection for a variety of ice accumulation scenarios (tailplane, supercooled large droplets, thin, rough ice accumulations, etc.).

17. The guidance provided by Comair in its memos, bulletins, manuals, and training program did not adequately communicate or emphasize specific minimum airspeeds for operating the EMB-120 in the flaps-up configuration, in or out of icing conditions, and thus contributed to the accident.

18. The pilots likely did not recognize the need to abide by special restrictions on airspeeds that were established for icing conditions because they did not perceive the significance (or presence) of Comair flight 3272's ice accumulation.

19. Whether the pilots perceived ice accumulating on the airplane or not, they should have recognized that operating in icing conditions at the air traffic control-assigned airspeed of 150 knots with flaps retracted could result in an unsafe flight situation; therefore, their acceptance of the 150-knot airspeed assignment in icing conditions without extending flaps contributed to the accident.

20. Minimum airspeed information for various flap configurations and phases and conditions of flight would be helpful to pilots of all passenger-carrying airplanes.

21. The stall warning system installed in the accident airplane did not provide an adequate warning to the pilots because ice contamination was present on the airplane's airfoils, and the system was not designed to account for aerodynamic degradation or adjust its warning to compensate for the reduced stall warning margin caused by the ice.

22. The accident airplane's autopilot was capable of normal operation and appeared to be operating normally during the last minutes of the accident flight, and the autopilot disconnect and warning systems operated in a manner consistent with their design logic.

23. Had the pilots been flying the airplane manually (without the autopilot engaged) they likely would have noted the increased right-wing-down control wheel force needed to maintain the desired left bank, become aware of the airplane's altered performance characteristics, and increased their

airspeed or otherwise altered their flight situation to avoid the loss of control.

24. Disengagement of the autopilot during all operations in icing conditions is necessary to enable pilots to sense the aerodynamic effects of icing and enhance their ability to retain control of the airplane.

25. If the pilots of Comair flight 3272 had received a ground proximity warning system, autopilot, or other system-generated cockpit warning when the airplane first exceeded the autopilot's maximum bank command limits with the autopilot activated, they might have been able to avoid the unusual attitude condition that resulted from the autopilot's sudden disengagement.

26. Despite the accumulated lessons of several major accidents and (in the case of the EMB-120) the specific findings of a staff engineer, the Federal Aviation Administration failed to adopt a systematic and proactive (rather than incremental and reactive) approach to the certification and operational issues of turbopropeller-driven transport airplane icing, which was causal to this accident.

27. The icing certification process has been inadequate because it has not required manufacturers to demonstrate the airplane's flight handling and stall characteristics under a sufficiently realistic range of adverse ice accretion/flight handling conditions.

28. The work conducted by the Federal Aviation Administration Environmental Icing National Resource Specialist and the Aviation Rulemaking Advisory Committee's icing-related working groups is of crucial importance to the future safety of icing operations.

29. The potential consequences of operating an airplane in icing conditions without first having thoroughly demonstrated adequate handling/controllability characteristics in those conditions are sufficiently severe that they warrant as thorough a certification test program as possible, including application of revised standards to airplanes currently certificated for flight in icing conditions.

30. The current Federal Aviation Administration policy allowing air carriers to elect not to adopt airplane flight manual operational procedures without clear written justification can result in air carriers using procedures that may not reflect the safest operating practices.

31. At the time of the Comair flight 3272 accident, pertinent flight standards personnel (specifically, the principal operations inspector assigned to Comair) lacked information critical to the continued safe operation of the EMB-120 fleet and would have been unable to evaluate the need to

incorporate airplane flight manual revision 43 or any alternatives proposed by air carriers.

32. The Federal Aviation Administration's current EMB-120 flight data recorder system inspection procedure is inadequate because it allows existing flight control sensor anomalies to go undetected, and thus uncorrected.

33. The failure of pilots who encounter in-flight icing to report the information to the appropriate facility denies other pilots operating in the area the access to valuable and timely information that could prevent an accident.

34. The Federal Aviation Administration air traffic control system has not established adequate procedures for the dissemination of icing-related pilot reports received in the airport terminal environment; these reports should be incorporated into automatic terminal information service broadcasts so that all arriving and departing pilots can become aware of icing conditions in the area.

3.2 Probable Cause

The National Transportation Safety Board determines that the probable cause of this accident was the FAA's failure to establish adequate aircraft certification standards for flight in icing conditions, the FAA's failure to ensure that a Centro Tecnico Aeroespacial/FAA-approved procedure for the accident airplane's deice system operation was implemented by U.S.-based air carriers, and the FAA's failure to require the establishment of adequate minimum airspeeds for icing conditions, which led to the loss of control when the airplane accumulated a thin, rough accretion of ice on its lifting surfaces.

Contributing to the accident were the flightcrew's decision to operate in icing conditions near the lower margin of the operating airspeed envelope (with flaps retracted), and Comair's failure to establish and adequately disseminate unambiguous minimum airspeed values for flap configurations and for flight in icing conditions.