National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: March 5, 2004

In reply refer to: A-04-4 through -24

Honorable Marion C. Blakey
Administrator
Federal Aviation Administration
Washington, DC 20591

On January 8, 2003, about 0847:28 eastern standard time, Air Midwest (doing business as US Airways Express) flight 5481, a Raytheon (Beechcraft) 1900D,[1] N233YV, crashed shortly after takeoff from runway 18R at Charlotte-Douglas International Airport, Charlotte, North Carolina. The 2 flight crewmembers and 19 passengers aboard the airplane were killed, 1 person on the ground received minor injuries, and the airplane was destroyed by impact forces and a postcrash fire. Flight 5481 was a regularly scheduled passenger flight to Greenville-Spartanburg International Airport, Greer, South Carolina, and was operating under the provisions of 14 *Code of Federal Regulations* (CFR) Part 121 on an instrument flight rules flight plan. Visual meteorological conditions prevailed at the time of the accident.

The National Transportation Safety Board determined that the probable cause of this accident was the airplane's loss of pitch control during takeoff. The loss of pitch control resulted from the incorrect rigging of the elevator control system[2] compounded by the airplane's aft center of gravity (CG), which was substantially aft of the certified aft limit.[3]

[1] Raytheon Aircraft Company acquired Beech Aircraft Corporation in February 1980.

[2] Between the night of January 6 and the morning of January 7, 2003, the accident airplane underwent a detail six (D6) maintenance check at Air Midwest's Huntington, West Virginia (HTS), maintenance station. (The detail check is divided into six different phases, known as detail one through detail six, and a different phase is performed every 200 flight hours. One major airplane section is inspected during each phase, and the D6 check covers the aft fuselage and empennage.) Part of the D6 maintenance check involved checking the tension of the elevator control system cables and adjusting the tension, if necessary, according to the elevator control system rigging procedure (section 27-30-02) in the Beech 1900D Airliner Maintenance Manual (AMM). The Safety Board concluded that the accident airplane's elevator control system was incorrectly rigged during the D6 maintenance check and that the incorrect rigging restricted the airplane's elevator travel to 7º airplane nose down (AND), or about one-half of the downward travel specified by the airplane manufacturer (14º to 15º AND).

[3] According to the Air Midwest Beechcraft 1900D Load Manifest, flight 5481 had a calculated CG position of 37.8 percent mean aerodynamic chord (MAC). The airplane performance study for flight 5481 determined that the accident airplane's actual CG position was about 45.5 percent MAC. As a result, flight 5481 had exceeded the Beech 1900D certified aft CG limit of 40 percent MAC. The restricted elevator travel alone (described in footnote 2) and the aft CG alone would not have been sufficient to cause the uncontrolled pitchup that led to the flight 5481 accident. The Safety Board concluded that flight 5481 had an excessive aft CG, which, combined with the reduced downward elevator travel resulting from the incorrect elevator rigging, rendered the airplane uncontrollable in the pitch axis.

Contributing to the cause of the accident were (1) Air Midwest's lack of oversight of the work being performed at the HTS maintenance station; (2) Air Midwest's maintenance procedures and documentation; (3) Air Midwest's weight and balance program at the time of the accident; (4) the Raytheon Aerospace[4] quality assurance inspector's failure to detect the incorrect rigging of the elevator control system; (5) the Federal Aviation Administration's (FAA) average weight assumptions in its weight and balance program guidance at the time of the accident; and (6) the FAA's lack of oversight of Air Midwest's maintenance program and its weight and balance program.[5]

Skipped Steps in the Elevator Control System Rigging Procedure

The Beech 1900D elevator control system rigging procedure (section 27-30-02) does not include provisions for adjusting cable tension as an isolated task. However, the SMART mechanic decided to adjust the cables as an isolated task and, as a result, did not follow each step included in the rigging procedure. The RALLC quality assurance inspector was aware that the mechanic was selectively performing steps from the rigging procedure and that he was only adjusting cable tension. In fact, the inspector stated, during a postaccident interview, that he did not think the manufacturer intended for mechanics to follow the entire rigging procedure and that the entire procedure had not been followed when past cable tension adjustments were made.

The mechanic skipped nine applicable steps in the Beech 1900D elevator control system rigging procedure.[6] One of these steps indicated that, for airplanes equipped with an F-1000 flight data recorder (FDR), the pitch position potentiometer needed to be calibrated (step u). The mechanic was required to perform this step because the accident airplane had an F-1000 FDR installed. Step u indicated that, to calibrate the pitch position potentiometer, the mechanic needed to perform the FDR pitch adjustment procedure described in another section of the Beech 1900D AMM. This procedure referred the mechanic to a table that specified eight different elevator settings, ranging from 14º AND to 20º airplane nose up (ANU), including 0º, and instructed the mechanic to record the FDR readout for these settings. The mechanic, however,

[4] Air Midwest contracted with Raytheon Aerospace, LLC (RALLC), to provide mechanics, quality assurance inspectors, and a site manager for the HTS maintenance station. RALLC contracted with Structural Modification and Repair Technicians, Inc. (SMART), to supply the mechanic workforce. RALLC (the maintenance contractor) and Raytheon Aircraft Company (the airplane manufacturer) were separate entities. On June 20, 2003, RALLC changed its name to Vertex Aerospace, LLC. On December 1, 2003, L-3 Communications acquired Vertex Aerospace and named the new business unit L-3 Communications AeroTech, LLC.

[5] For more information, see National Transportation Safety Board, *Loss of Pitch Control During Takeoff, Air Midwest Flight 5481, Raytheon (Beechcraft) 1900D, N233YV, Charlotte, North Carolina, January 8, 2003*, Aircraft Accident Report NTSB/AAR-04/01 (Washington, DC: NTSB, 2004).

[6] The Safety Board is aware of another recent instance in which mechanics skipped a step of a Beech 1900D AMM procedure. Specifically, the investigation into the August 26, 2003, Colgan Air flight 9446 accident determined that the mechanics had to replace both elevator trim tab actuators because of excessive freeplay. Beech 1900D AMM section 27-30-06 required the mechanics to remove the elevators before the actuators were replaced. However, the mechanics skipped that procedural step and replaced the actuators with the elevators installed. Additional information about this accident, NYC03MA183, can be found on the Safety Board's Web site at <http://www.ntsb.gov>.

would not have been able to move the elevator to the first setting, 14º AND, because elevator travel was restricted to about 7º AND.

The performance of step u would have likely alerted the mechanic or the quality assurance inspector that the elevator control system was not properly rigged. However, the mechanic indicated that he skipped step u because he thought the calibration did not need to be done. The quality assurance inspector stated that he did not think that an FDR was installed on the airplane, but the inspector should have known that the airplane was equipped with an FDR because most, if not all, Beech 1900D airplanes were outfitted with an FDR. Also, the inspector could have easily determined that the airplane was equipped with an FDR. Specifically, the wiring and the sensor for the FDR were in the same area of the airplane where maintenance was being performed. Also, the FDR unit is mounted in the forward (AFT1) cargo compartment and is readily visible. In addition, a circuit breaker for the FDR is located in the cockpit.

Title 14 CFR 121.367 states that aircraft maintenance, preventive maintenance, and alterations are to be performed in accordance with operators' maintenance manuals. Thus, maintenance personnel are expected to follow all procedural steps unless authorization has been granted. The SMART mechanic and RALLC quality assurance inspector were not authorized to decide whether a specific step of the maintenance manual could be skipped. Air carriers have procedures in place for making such determinations on a one-time or short-term basis. These determinations are made by managers and engineers in accordance with the air carrier's maintenance manual.[7]

For long-term changes, the Continuing Analysis and Surveillance System (CASS) is used to change an air carrier's maintenance procedure if it is deficient or needs correction. Title 14 CFR 121.373(a), "Continuing Analysis and Surveillance," requires operators to establish and maintain a system for the continuing analysis and surveillance of the performance and effectiveness of their maintenance and inspection programs and for the correction of any deficiency found in those programs. Also, FAA Advisory Circular (AC) 120-16D, "Continuous Airworthiness Maintenance Programs," states that CASS programs must ensure that all elements of an air carrier's maintenance program are being accomplished in accordance with its maintenance manual and that any deficiencies in an air carrier's manual are identified and corrected. The findings of the flight 5481 investigation suggest that air carriers may not have adequate CASS programs despite the requirements of 14 CFR 121.373.

The Safety Board concludes that, because the RALLC quality assurance inspector and the SMART mechanic did not diligently follow the elevator control system rigging procedure as written, they missed a critical step that would have likely detected the misrig and thus prevented the accident. Therefore, the Safety Board believes that the FAA should adopt a program for performing targeted surveillance and increased oversight of maintenance practices at 14 CFR Part 121 air carriers to ensure that maintenance instructions are being followed as written and that maintenance personnel (including, but not limited to, management, quality assurance,

[7] The Air Midwest General Maintenance Manual required that deviations to maintenance procedures be approved by the FAA, but the HTS maintenance station did not have the necessary support during the night shift to receive such approval.

tooling, and training personnel, as well as mechanics) are following all steps in the instructions unless authorization has been granted in accordance with the air carrier's maintenance program. In addition, the Safety Board believes that the FAA should verify that 14 CFR Part 121 air carriers have procedures in their CASS program for identifying deficiencies and incorporating changes to the carrier's maintenance program and that maintenance personnel for these air carriers (including, but not limited to, management, quality assurance, tooling, and training personnel, as well as mechanics) use these procedures.

Lack of an Effective Postmaintenance Check

The mechanic indicated that he conducted control sweeps from the cockpit after the cable tension had been adjusted. He stated that he "ran the elevator full travel a few times" and then checked the cable tensions to make sure that they had not changed. However, the mechanic also stated that no one was at the tail of the airplane observing the elevator travel when he conducted the control sweeps.

The quality assurance inspector stated that he observed the elevator at a neutral position on the travel board with the rig pin installed at the forward bellcrank. The inspector also stated that, after the rig pin was removed, he grasped the elevator with the travel board still attached and moved the elevator throughout the available travel. The inspector thought that the elevator could be fully deflected with the forward bellcrank rig pin removed and stated that elevator travel was "within limits." However, results from the Safety Board's investigation, including simulations, ground tests, and FDR data, indicated that elevator travel could not have been within the limits specified in Beech 1900D AMM section 27-30-02. The quality assurance inspector further stated that he was present when the mechanic verified cable tension by attaching a tensiometer on both cables and checking the tensions.

The postmaintenance checks performed by the quality assurance inspector and the mechanic were not adequate to detect the elevator control system misrig. If step u of the rigging procedure (the calibration of the pitch control position potentiometer) had been performed on the accident airplane, it is likely that the quality assurance inspector and the mechanic would have caught the misrigging problem. Also, if a functional check had been included at the end of the procedure, the quality assurance inspector and the mechanic would have had another opportunity to detect the misrigging problem. A functional check at the end of the procedure would have provided a more comprehensive, systematic, and direct method to ensure that any misrigging problem was caught before an airplane was returned to service.[8] Such a functional check would consist of a mechanic in the cockpit pushing the control wheel full forward and then pulling the wheel full aft while another mechanic, who was at eye level with the horizontal stabilizer, measured the position of the elevator using a travel board. This process would determine whether the elevator achieved the correct deflection for the full forward and full aft movement of the control column.

[8] The Safety Board notes that some elevator control system maintenance procedures do not include an FDR check and that FDRs can be placed on an air carrier's minimum equipment list, as was the case with Colgan Air flight 9446.

The Safety Board recognizes that Raytheon Aircraft Company added a postmaintenance functional check to its revised elevator control system rigging procedure issued on February 12, 2003. Specifically, step aa indicates that the mechanic is to move the control wheel aft and forward and verify that the elevator moves up 20º +1º/-0º and down 14º +1º/-0º, respectively, and that the control stops make contact.

The lack of a functional check at the end of a maintenance procedure is also an issue with the Colgan Air flight 9446 accident. During the replacement of the elevator trim tab actuators, the mechanics thought that the forward elevator trim tab cable had become jammed or kinked and thus needed to be replaced. The mechanics tried to replace the cable in accordance with Beech 1900D AMM section 27-30-04. This procedure does not describe in detail how to manipulate the electric and manual trim systems in each direction and verify that the full range of motion in the commanded direction is observed at the trim tabs. The mechanics stated, during a postaccident interview, that they moved the trim tabs through a full range of motion using the electric and manual systems and observed no anomalies. However, without a detailed procedure to ensure that the trim tabs are moving in the proper direction, it is possible that the trim tabs could move in a reversed direction and remain unnoticed.

In addition, the investigation of the October 16, 2003, CommutAir flight 8718 incident[9] determined that the mechanic did not perform a functional test of the elevator trim control system, as required by FAA Airworthiness Directive (AD) 2003-20-10. A functional check of the system would have indicated that the elevator trim wheel had been reinstalled incorrectly.

The Safety Board concludes that a complete functional check at the end of maintenance for critical flight systems[10] or their components would help to ensure their safe operation, but no such check is currently required. Therefore, the Safety Board believes that the FAA should modify (1) appendix G of 14 CFR Part 23 and appendix H of 14 CFR Part 25 and (2) 14 CFR 121.369 to require that the Instructions for Continued Airworthiness and air carrier maintenance manuals, respectively, include a complete functional check at the end of maintenance for each critical flight system. The Safety Board also believes that the FAA should require manufacturers of aircraft operated under 14 CFR Part 121 to identify appropriate procedures for a complete functional check of each critical flight system; determine which maintenance procedures should be followed by such functional checks; and modify their existing maintenance manuals, if necessary, so that they contain procedures at the end of maintenance for a complete functional check of each critical flight system. The Safety Board further believes that the FAA should require 14 CFR Part 121 air carriers to modify their existing maintenance manuals, if necessary, so that they contain procedures at the end of maintenance for a complete functional check of each critical flight system.

[9] Additional information about this incident, NYC04IA010, can be found on the Safety Board's Web site.

[10] A flight system is considered critical if its failure can be catastrophic.

Organizational and Management Factors – Air Midwest

Required Inspection Item Maintenance Tasks and Inspections

Air Midwest's Maintenance Procedures Manual states that elevator control system rigging is a required inspection item (RII), which means that maintenance work performed on the system must be inspected before the airplane can be returned to service. Title 14 CFR 121.371(c) states, "no person may perform a required inspection if [that person] performed the item of work required to be inspected." The aircraft maintenance record of nonroutine items for January 6, 2003, at HTS showed, in a discrepancy block about the airplane's low elevator cable tension, an RII stamp and the quality assurance inspector's stamp.

RII maintenance tasks that are not performed properly could result in a failure, malfunction, or defect that would endanger the safe operation of the airplane. Thus, it is imperative to have an independent inspection of RII maintenance tasks by a second, fully qualified mechanic to ensure that the work has been properly completed. Current regulations do not explicitly prohibit inspectors from training a mechanic on a task and then inspecting that same task.[11] However, the inspectors cannot properly fulfill their RII responsibilities in such a situation. The purpose of an RII inspection is to provide "a second set of eyes" to ensure that any error made in performing maintenance work is detected and corrected before an airplane is returned to service. The Safety Board concludes that, when an inspector provides on-the-job training (OJT) for an RII maintenance task and then inspects that same task, the independent nature of the RII inspection is compromised. Therefore, the Safety Board believes that the FAA should prohibit inspectors from performing RII inspections on any maintenance task for which the inspector provided OJT to the mechanic who accomplished the task.

According to AC 120-16D, Air Midwest was responsible for overseeing the performance of RII inspections. In fact, Air Midwest acknowledged in its contract with RALLC that Air Midwest would be responsible for quality control and quality assurance inspections. However, oversight of the quality assurance function at HTS went through two different levels of management at RALLC (the Regional Airline Maintenance Service [RAMS] quality assurance manager in Panama City, Florida, and the RAMS Executive Program Manager for Airline Support in Madison, Mississippi) before becoming the responsibility of the Air Midwest Director of Quality Assurance in Wichita, Kansas. In addition, the only Air Midwest employee at HTS (the regional site manager) normally worked the day shift, and he was only sporadically present when the maintenance work and inspections were being accomplished. As a result, Air Midwest was not sufficiently overseeing the RII inspections at HTS, which is especially troublesome considering the importance of these inspections.

[11] On March 26, 2003, the quality assurance inspector at HTS on the night of January 6, 2003, was advised that the FAA would be investigating the inspector's actions in "giving on-the-job training after work was assigned." On September 30, 2003, the FAA notified the inspector that the investigation "did not establish a violation of the Federal Aviation Regulations [FARs]." (The FAA also investigated the mechanic's actions "involving work being accomplished" and the foreman's actions "involving work being assigned," and the investigation found that their actions did not violate the FARs.)

Sufficient oversight of RII maintenance tasks and inspections requires air carrier personnel to maintain an on-site presence and to be thoroughly involved in, and familiar with, all aspects of a maintenance facility's operations relating to RII tasks and inspections. Such oversight requires, at a minimum, that air carrier personnel be physically present when a substantial amount of the RII planning, tasking, maintenance work, and inspections are performed and that air carrier personnel be readily available when they are not physically present. In addition, air carriers need to ensure that the processes and procedures used by contractors to perform RII maintenance tasks and inspections are the same as those used by air carrier maintenance personnel.

The Safety Board concludes that air carriers that use contractors to perform RII maintenance tasks and inspections need to provide substantial and direct oversight during each work shift to ensure that this work is being properly conducted. Therefore, the Safety Board believes that the FAA should require 14 CFR Part 121 air carriers that use contractors to perform RII maintenance tasks and inspections to have air carrier personnel who are physically present when a substantial amount of the RII planning, tasking, maintenance work, and inspections are performed and are readily available when they are not physically present and who ensure that the processes and procedures used by contractors to perform RII maintenance tasks and inspections are the same as those used by air carrier maintenance personnel.

Maintenance Training Guidelines

Air Midwest required mechanics to complete OJT for a procedure before they could perform that procedure unsupervised. However, Air Midwest had little guidance on how to effectively provide OJT.

The only guidance in Air Midwest's Maintenance Training Manual about OJT as a training method stated that (1) OJT would teach knowledge and practical skills of normal job-related duties and would include practical situations found every day on the job and (2) OJT would be performed under the guidance of a qualified technician or staff member who has documentation of previously received OJT. The Maintenance Training Manual did not include other issues related to the delivery of OJT, including how many students should be permitted per instructor, how tasks should be demonstrated before being performed, how the learning environment should be controlled, and how to ensure that the skills learned through OJT would be retained.

Because Air Midwest lacked specific OJT guidance, the OJT provided to new mechanics at the HTS maintenance station varied based on the instructors' teaching style. For example, the quality assurance inspector on the night of January 6, 2003, stated, during a postaccident interview, that it was not necessary to "hold [a mechanic's] hand" if he thought the mechanic knew what he was doing based on past experience. Also, the mechanic who performed the elevator cable inspection and adjustments on the accident airplane indicated that it was routine for mechanics to work independently during OJT and receive little supervision. However, a mechanic who assisted the quality assurance inspector with an engine borescope inspection on the night of January 6th stated that, when he last received OJT, the instructor (who was at HTS

from the Panama City maintenance station) walked him through the task "step by step." The Safety Board concludes that Air Midwest did not have maintenance training policies and procedures in place to ensure that each of its maintenance stations had an effective OJT program.

Air carriers are required by 14 CFR 121.367(b) to ensure the competence of their maintenance personnel for the proper performance of maintenance, preventive maintenance, and alterations. However, according to AC 120-16D, FAA regulations contain the flexibility necessary to allow each air carrier to develop a training program that fits its particular needs. Many air carriers have provided, and will continue to provide, airplane-specific maintenance training through OJT programs.

During a 1993 Safety Board public hearing on commuter airline safety, representatives from the commuter airline industry indicated that the quality of air carrier maintenance training varied throughout the industry, with some airlines doing an excellent job of training mechanics and other airlines providing mechanics with only minimal training.[12] Also, a 1998 FAA study of personnel training and qualifications at aviation maintenance facilities[13] found that, although airline mechanics reported that they were generally satisfied with the maintenance training provided by their companies, one area of concern involved informal OJT. Specifically, a significant number of mechanics indicated that they would prefer OJT that was more formal, with task objectives, checklists, and specific task signoffs. In addition, the FAA's 1998 *Guide for Human Factors in Aviation Maintenance and Inspection*[14] stated that OJT had several positive aspects but that OJT practices were lax and tended to be unstructured.

The FAA's *Guide for Human Factors in Aviation Maintenance and Inspection* contained voluntary guidelines for developing structured OJT programs. However, air carriers are not currently required to follow these guidelines when developing OJT programs. The Safety Board concludes that it is important that air carrier OJT programs are developed in accordance with detailed guidance that emphasizes effective training practices. Therefore, the Safety Board believes that the FAA should develop detailed OJT requirements for 14 CFR Part 121 air carriers that rely on OJT as a maintenance training method. These requirements should include, but not be limited to, best practices, procedures, and methods for accomplishment and administration of this training. The Safety Board also believes that the FAA should ensure that these OJT requirements are incorporated into 14 CFR Part 121 air carrier maintenance training programs.

Maintenance Training Oversight

The Safety Board identified deficiencies in Air Midwest's oversight of its maintenance training program. First, because only one RALLC quality assurance inspector and one RALLC foreman (the backup quality assurance inspector) worked at HTS at the time of the accident, a

[12] For more information, see National Transportation Safety Board, *Commuter Airline Safety*, Special Study NTSB/SS-94/02 (Washington, DC: NTSB, 1994).

[13] R.P. Goldsby and J. Watson, *Comparative Study of Personnel Training and Qualifications at Aviation Maintenance Facilities* (Washington, DC: Office of Aviation Medicine, FAA, 1998).

[14] Maddox, M. (Ed.) *Human Factors Guide for Aviation Maintenance and Inspection, Version 3.0* (Atlanta, GA: Galaxy Scientific Corporation, 1998).

SMART mechanic was appointed as foreman 4 nights per week (when the quality assurance inspector was not on duty and the foreman assumed the inspector's responsibilities). One of the foreman's responsibilities was to follow the progress of the mechanics in accomplishing the assigned maintenance work. However, the SMART mechanic who was the foreman on the night of January 6, 2003, had not completed OJT for the Beech 1900D.

Second, according to Air Midwest's Maintenance Procedures Manual, the foreman was responsible for ensuring that OJT was provided to mechanics by someone other than the quality assurance inspector. However, the quality assurance inspector routinely provided OJT. In fact, the quality assurance inspector on duty on the night of January 6th stated that he had received most of his training at Mesa Airlines, Arctic Slope, and Air Midwest from inspectors and that he believed it was standard practice for inspectors to provide OJT. Also, the foreman stated that a quality assurance inspector had been providing OJT to mechanics since he began working for RALLC in December 2001.

The Air Midwest regional site manager was aware that inspectors were providing most of the OJT because he reviewed maintenance training records on a daily basis. However, the regional site manager should have been aware that this situation increased the inspector's workload (providing OJT and performing RII inspections) and did not separate maintenance and inspection tasks. The quality assurance inspector stated that the regional site manager never mentioned to him that inspectors should not provide OJT.

Last, according to Air Midwest's Maintenance Training Manual and Maintenance Procedures Manual, the regional site manager was responsible for maintaining training records and ensuring that the training was properly documented. As previously stated, the regional site manager reviewed maintenance training records daily, and he indicated that he attempted to have discrepancies corrected quickly. The regional site manager forwarded the training records to Air Midwest's Maintenance Training Coordinator in Wichita, who reviewed the records for completeness and accuracy. However, an FAA inspection conducted by geographic inspectors from the Charleston, West Virginia, Flight Standards District Office 2 days after the accident found that maintenance training records for employees at HTS were "not complete or current." Also, the Safety Board discovered numerous discrepancies in the training records of HTS maintenance personnel, including the following:

- The mechanic who performed the elevator control cable work had his training records signed as complete for the D6 aft fuselage/empennage inspection procedure and for "rudder, aileron, or elevator cable tension adjustment" by the quality assurance inspector. However, the mechanic had not been trained on the rudder and aileron rigging procedures. Air Midwest's maintenance training program considered mechanics to be fully trained on all three major control cable rigging procedures after the mechanics had received training on only one of the procedures, despite significant differences among the procedures.

- Another SMART mechanic and the primary quality assurance inspector incorrectly indicated on that mechanic's OJT record that he had completed

training on the D6 aft fuselage/empennage inspection procedure on January 6th. The mechanic inspected and checked the engines but did not perform the entire D6 procedure, including the elevator check.

- The mechanics that were on duty on the night of January 6th had numerous items (dating as far back as December 14, 2002) signed as complete in their training records, but these items did not have the required instructor signature stamps.

- The foreman's training records indicated that he had received OJT for the detail 2 through detail 5 checks all on the same day. It is unrealistic for any mechanic to have completed OJT for all those tasks on a single day because one detail check generally takes an entire shift to complete.

Further, the Air Midwest principal maintenance inspector (PMI) stated that the FAA has had longstanding concerns with Air Midwest's management of its maintenance training program. These concerns included that mechanics received no formal (classroom) training, OJT records were not being properly maintained, no one was adequately monitoring the quality of the OJT provided, and the training was not consistent with guidelines set forth in Air Midwest's Maintenance Training Manual. Letters from the FAA to Air Midwest showed that, during a 2-year period beginning in October 2000, the FAA had encouraged Air Midwest to improve its maintenance training program. However, evidence discovered during the investigation of the flight 5481 accident showed that deficiencies still existed in Air Midwest's maintenance training program.

The Safety Board concludes that Air Midwest did not ensure that its maintenance training was conducted and documented in accordance with the company's maintenance training program, which degraded the quality of training and inspection activities at the HTS maintenance station. Because of the numerous discrepancies in the training records of HTS maintenance personnel, the Safety Board believes that the FAA should audit training records for personnel who are currently performing maintenance on Air Midwest airplanes to verify that the training was properly accomplished in accordance with the company's Maintenance Procedures Manual and Maintenance Training Manual.

Detail 6 Inspection Procedures Checklist

The Air Midwest D6 inspection procedures checklist (also known as the D6 work card) was the document that mechanics used for inspecting and adjusting elevator control cables. The work card referred the mechanics to the Beech 1900D AMM for additional details regarding the cable inspection and adjustments. The work card and the AMM contained general instructions to guide the mechanics in performing these tasks.

The D6 work card instructed mechanics to check cable tension according to Beech 1900D AMM chapter 27.[15] However, the D6 work card did not specifically refer the mechanics to section 27-30-02 of the AMM, which contained the only reference—an elevator cable tension graph—in chapter 27 for determining cable tension. Further, to use the graph, the mechanic was first required to determine cable temperature, but neither the D6 work card nor the elevator cable tension graph described how to prepare the airplane for temperature measurement or how and where to obtain temperature readings. The Safety Board's ground tests showed that temperature readings varied depending on the method used by individual mechanics for measuring cable temperature and that the method used for measuring temperature could affect cable tension.

Interviews with Air Midwest and Raytheon Aircraft Company officials revealed that, when cable tension was found to be outside of acceptable parameters, mechanics were expected to perform the entire elevator control system rigging procedure. Neither the D6 work card nor the Beech 1900D AMM explicitly stated that the entire rigging procedure needed to be performed or that the elevator cable tension adjustment could not be accomplished as an isolated task.

Maintenance procedures are developed and are expected to be followed to ensure that maintenance work is properly performed. When a maintenance procedure contains multiple steps that are not applicable to the airplane on which a mechanic is working,[16] a mechanic may decide to skip applicable steps. Although well-trained mechanics may be more capable of distinguishing between steps that are and are not applicable to a particular aircraft than mechanics with less training, maintenance procedures should be written so they minimize the possibility that any mechanic would need to make such distinctions. Errors can be made if applicable steps are skipped along with inapplicable steps, as demonstrated by the elevator control system maintenance on the accident airplane. Mechanics would be less likely to skip applicable steps and more likely to follow a maintenance procedure in its entirety if the procedure were well written.

The FAA has sponsored human factors research regarding the quality of maintenance procedures and instructions, and this research has found a link between the usability of maintenance procedures and the likelihood that mechanics will follow the procedures. For example, a 2002 survey[17] found that only 18 percent of mechanics thought that their organization's maintenance manual described the best way to perform a maintenance procedure. The survey also found that 62 percent of the mechanics had performed maintenance using methods that they considered to be better than those detailed in their organization's written procedures. The results of the survey suggest that the usability of work cards may be a factor

[15] The only other details provided on the work card regarding elevator cable tensioning were blank lines on which a mechanic recorded the cable temperature and the number of pounds of tension for the ANU and AND cables.

[16] Three steps in section 27-30-02 were not applicable to the accident airplane. Two steps pertained to the autopilot, but the airplane was not equipped with an autopilot. One step pertained to the removal of passenger seats and passenger cabin floorboards, but the airplane's elevator cable turnbuckles were not located beneath those components.

[17] A. Chaparro, and L.S. Groff, "Human Factors Survey of Aviation Maintenance Technical Manuals," *Proceedings of the 16th Human Factors in Aviation Maintenance Symposium* (Washington, DC: FAA, 2002).

affecting whether mechanics will adhere to their organization's accepted procedures when performing maintenance.

In its final report on the Emery Airlines flight 17 accident,[18] the Safety Board determined that unclear maintenance work card instructions might have contributed to maintenance errors involved in that accident. The Board concluded that all air carriers should provide maintenance personnel with more detailed information regarding the steps or actions that are necessary to satisfactorily accomplish a maintenance task. Also, the Board issued Safety Recommendation A-03-31, which asked the FAA to "require all 14 CFR Part 121 air carrier operators to revise their task documents and/or work cards to describe explicitly the process to be followed in accomplishing maintenance tasks."

The mechanics' failure to follow the general guidance provided on Air Midwest's D6 work card and in the Beech 1900D AMM supports the need for the actions recommended in Safety Recommendation A-03-31. However, Safety Recommendation A-03-31 focused only on the role of the air carrier in revising work cards and did not consider the safety benefit of involving the aircraft manufacturer in the process of reviewing and revising maintenance procedures. Placing this responsibility solely on air carriers raises the possibility that individual carriers could identify deficiencies in flight-critical maintenance procedures but fail to share this information with other air carriers that operate the same airplane. If aircraft manufacturers were involved in the process of reviewing and revising maintenance procedures, safety information would more likely be shared among air carriers.

In addition, the flight 5481 accident demonstrated that the usability of aircraft maintenance manuals is as important to safety as the usability of work cards, but Safety Recommendation A-03-31 did not address the added safety benefit of revising procedures contained in aircraft maintenance manuals. As a result, the Safety Board classifies Safety Recommendation A-03-31 "Closed—Superseded."

The Safety Board concludes that accurate and usable work cards developed jointly by air carriers and aircraft manufacturers would improve the performance of maintenance for critical flight systems. Therefore, the Safety Board believes that the FAA should require 14 CFR Part 121 air carriers to implement a program in which carriers and aircraft manufacturers review all work card and maintenance manual instructions for critical flight systems and ensure the accuracy and usability of these instructions so that they are appropriate to the level of training of the mechanics performing the work.

[18] For more information, see National Transportation Safety Board, *Loss of Pitch Control on Takeoff, Emery Worldwide Airlines, Inc., Flight 17, McDonnell Douglas DC-8-71F, N8079U, Rancho Cordova, California, February 16, 2000*, Aircraft Accident Report NTSB/AAR-03/02 (Washington, DC: NTSB, 2003).

Organizational and Management Factors – Federal Aviation Administration

Oversight of Continuing Analysis and Surveillance System Programs

The FAA developed the requirement for air carrier CASS programs so that the carriers would have internal quality control systems to reduce safety hazards and improve operational performance. However, the regulation requiring air carrier CASS programs—14 CFR 121.373—did not describe program requirements in detail. The primary CASS program guidance that was in effect at the time of the flight 5481 accident was contained in FAA AC 120-16C, "Continuing Airworthiness Maintenance Programs," and was less than 1 page in length.

After the January 31, 2000, Alaska Airlines flight 261 accident[19] and an FAA postaccident inspection of the air carrier, the Department of Transportation Office of Inspector General conducted an investigation of the FAA's oversight of CASS programs. The office's December 12, 2001, report on the investigation stated that the findings of the FAA's postaccident inspection raised questions regarding why the FAA's routine surveillance had not identified deficiencies in Alaska Airlines' CASS program and ensured that they were corrected. The report also stated that the FAA "placed limited emphasis on CASS in its oversight" and recommended that the FAA improve CASS program oversight and expand existing program guidance to better describe what an effective CASS program should include.[20] In its comments on a draft of the report (dated October 4, 2001), the FAA agreed, among other things, to revise existing guidance for CASS development and implementation, conduct annual CASS inspections, develop CASS training for inspectors, and require that all inspectors be trained by January 2004.

In March 2003, the FAA revised AC 120-16C. The revised AC (AC 120-16D) presented expanded CASS guidance in a dedicated chapter that was several pages in length. The guidance indicated that an air carrier's CASS program should detect and correct air carrier maintenance program deficiencies through a closed-loop, continuous cycle of surveillance and investigations, data collection and analysis, corrective actions, and monitoring and feedback.

AC 120-16D stated that an air carrier's CASS program should monitor nine elements of the carrier's continuous airworthiness maintenance program, including its maintenance manual. The guidance also stated that a CASS program should include "detailed policy and procedures" for determining whether an air carrier needed to amend its maintenance program or manual and for making such amendments. In addition, the guidance stated, "proactive surveillance and analysis forecasts faults in your [the air carrier's] maintenance program or manual through the collection and analysis of a wide variety of data. It corrects those faults, including human factors issues, in advance of any specific event, accident, or incident." Further, the guidance stated that

[19] For more information, see National Transportation Safety Board, *Loss of Control and Impact With Pacific Ocean, Alaska Airlines Flight 261, McDonnell Douglas MD-83, N963AS, About 2.7 Miles North of Anacapa Island, California, January 31, 2000*, Aircraft Accident Report NTSB/AAR-02/01 (Washington, DC: NTSB, 2002).

[20] U.S. Department of Transportation, Office of the Secretary of Transportation, Office of Inspector General, *Oversight of Aircraft Maintenance, Continuing Analysis and Surveillance Systems, Federal Aviation Administration* (Washington, DC: Department of Transportation, 2001).

an air carrier's "CASS audit schedule should include…all manuals, publications, and forms [to ensure that they] are useable, current, accurate, and readily available to the user."

In April 2003, the FAA published AC 120-79, "Developing and Implementing a Continuing Analysis Surveillance System," which was a comprehensive guide for the development of CASS programs. The AC provided information on many CASS-related topics and described model CASS programs for air carriers in three different size ranges.

The Safety Board commends the FAA for issuing improved, detailed guidance for the development and implementation of CASS programs. However, the FAA has not yet included this guidance in FAA Order 8300.10, *Airworthiness Inspector's Handbook*.[21] Also, the FAA has not completed the development of CASS training for aviation safety inspectors. The Board notes that, on January 26, 2004, the FAA provided the Board with the draft lesson plan for the CASS portion of an air carrier indoctrination course that is to be taught to all new inspectors.[22] The Board hopes that the FAA will complete the development of CASS training and begin training aviation safety inspectors as soon as possible.

The Safety Board concludes that updated CASS guidance would help FAA aviation safety inspectors ensure that CASS programs are being effectively implemented at 14 CFR Part 121 air carriers. Therefore, the Safety Board believes that the FAA should include the CASS guidance from AC 120-16D, "Continuing Airworthiness Maintenance Programs," and AC 120-79, "Developing and Implementing a Continuing Analysis Surveillance System," in FAA Order 8300.10, *Airworthiness Inspector's Handbook.*

Oversight of Maintenance Training Programs

The Safety Board notes that, in contrast to other air carrier training programs, such as those for pilots, flight attendants, dispatchers, flight instructors, check airmen, and personnel handling hazardous materials,[23] maintenance training programs do not require formal approval by the FAA. For those training programs that require formal approval, the air carrier submits its program plans to the FAA, which reviews those plans and either approves them in writing or sends them back to the carrier for revision and resubmission. FAA staff indicated that managing the content of, and ensuring compliance with, air carrier training programs that are not approved (such as maintenance training programs) can be more difficult than for programs that are approved. As a result, the FAA's oversight of maintenance training programs may not be as effective as its oversight of air carrier training programs that are required to be approved.

The Safety Board concludes that, because proper aircraft maintenance is crucial to safety, air carrier maintenance training programs should be subject to the same standard that exists for other air carrier training programs (that is, FAA approval). Therefore, the Safety Board believes

[21] Inspector guidance on the CASS program is currently found in volume 2, chapter 65, and volume 3, chapter 37, of the handbook. These handbook sections were developed in 1992 and 1993, respectively.

[22] The FAA reported that the initial indoctrination course was taught during the week of January 12, 2004.

[23] See 14 CFR 121.401, "Training Program: General."

that the FAA should require that all 14 CFR Part 121 air carrier maintenance training programs be approved.

Programs to Reduce Human Error in Aircraft Maintenance

The FAA's research program on human factors in aviation maintenance has primarily resulted in the publication of guidance material and the promotion of voluntary human factors programs for the aviation industry. The Safety Board commends the FAA for its efforts to address issues related to human factors in aviation maintenance. However, major maintenance-related airplane accidents in the United States during the past decade suggest that the guidance for voluntary human factors programs may be insufficient to prevent accidents resulting from human error in aviation maintenance.

The Safety Board concludes that the lessons learned by the FAA through its human factors research program need to be used to develop mandatory programs to prevent human error in aviation maintenance. Therefore, the Safety Board believes that the FAA should require that 14 CFR Part 121 air carriers implement comprehensive human factors programs to reduce the likelihood of human error in aviation maintenance.

Oversight of Weight and Balance Programs

Flight 5481 clearly exceeded the Beech 1900D certified weight limit of 17,120 pounds and aft CG limit of 40 percent MAC, even though the flight crew adhered to Air Midwest's weight and balance program in effect at the time of the accident.[24] In addition, even Air Midwest's revised weight and balance program could result, in certain conditions, in an airplane operating with an unacceptably aft CG position.[25]

The Air Midwest weight and balance procedures used by the flight crew were based on the use of average weights for the flight crewmembers, crew baggage, passengers, personal items, carry-on baggage stored in the cabin, checked baggage, and carry-on baggage checked at the airplane and stored in the AFT1 cargo compartment.[26] The Air Midwest average passenger and checked baggage weight values were consistent with the FAA guidance detailed in AC 120-27C, "Aircraft Weight and Balance Control," and Flight Standards Handbook Bulletin for Airworthiness 95-14 and Flight Standards Handbook Bulletin for Air Transportation 95-15, "Adherence to Advisory Circular 120-27C, 'Aircraft Weight and Balance Control.'" However,

[24] According to Air Midwest's weight and balance program guidance at the time of the accident, the average weight for adult passengers was 175 pounds (November through April) and 170 pounds (May through October), including 10 pounds for items that are normally carried on board by passengers, such as handbags, briefcases, and laptop computers. The average weight for checked baggage was 25 pounds, and the average weight for carry-on baggage stowed in the AFT1 cargo compartment was also 25 pounds.

[25] Air Midwest revised its weight and balance program in May 2003. According to the revised program, the average weight for adult passengers increased to 200 pounds all year and still included 10 pounds for items that are normally carried on board by passengers. The average weight for checked baggage increased to 30 pounds, and the average weight for carry-on baggage stowed in the AFT1 cargo compartment decreased to 20 pounds.

[26] Air Midwest's weight and balance program at the time of the accident attributed 170 pounds for each pilot, 20 pounds for each crew bag (one per pilot), and 10 pounds for each article stored in the coat closet.

as demonstrated by the flight 5481 accident, these values did not ensure that the airplane would be operating within its certified weight and CG envelope.

Wreckage evidence indicated that 4 of the 31 bags aboard flight 5481 weighed more than 50 pounds. None of these bags were formally recorded on any of the flight's paperwork. The heaviest of the four bags weighed 69 pounds, 44 pounds more than the 25-pound average weight value attributed to it for weight and balance purposes. Although the Director of US Airways Express Training stated, in a postaccident interview, that any bag weighing up to 70 pounds was accounted for under the average baggage weight program, the program underestimated the average weight of each of the 31 bags by 4 pounds and, thus, the total baggage weight by at least 124 pounds.

AC 120-27C permits air carriers to assign the FAA's standard weight value (25 pounds) for each checked bag. The AC, however, does not provide guidance to air carriers regarding what weight cutoff should be used to avoid weight and balance errors resulting from heavy bags. In addition, flight crews, gate agents, and baggage handlers have only minimal guidance on how to recognize situations that necessitate the use of actual rather than average baggage weights.

The average weight of passengers aboard flight 5481 was 185 pounds, 10 pounds more than the 175-pound average weight value attributed to each passenger. Of the 19 passengers aboard the accident flight, 16 (about 84 percent) were male, and 3 (about 16 percent) were female. AC 120-27C stated that the standard average passenger weights "cannot be arbitrarily adopted for operations with passenger groups that appreciably differ from the basis or where the mix of male and female passengers is known to be different than a 60 percent male/40 percent female operation." However, neither the FAA's guidance nor Air Midwest's weight and balance program identified specific nonstandard passenger weight cues or thresholds to indicate when to use actual rather than average passenger weights.

The Safety Board concludes that the use of average weights does not necessarily ensure that an aircraft will be loaded within its weight and CG envelope. Therefore, the Safety Board believes that the FAA should identify those situations that would require the use of actual instead of average weights in weight and balance computations and should incorporate this information into AC 120-27, "Aircraft Weight and Balance Control."

Approval of Air Midwest's Weight and Balance Program

On April 9, 2001, the Air Midwest PMI approved the weight and balance procedures contained in the air carrier's operations specifications at the time of the accident. However, the PMI approved Air Midwest's weight and balance program without first validating the program. During the public hearing for this accident, an FAA air safety investigator from the Air Carrier Operations Branch stated that air carriers were responsible for evaluating the program's impact on weight and balance. The air safety investigator also stated that the air carrier was responsible for ensuring that its weight and balance program complied with the manufacturer's limitations and that the FAA was responsible for promoting safety and providing oversight.

According to the Air Midwest PMI, oversight of the air carrier's weight and balance program occurred only during en route inspections, when an inspector would check the cargo bin, count the number of bags, and look at the size of the bags and then compare the findings with the information on the load manifest. If the FAA had provided effective oversight by performing a survey to determine the average passenger and baggage weights, it would have realized that these weights were significantly different from the average passenger and baggage weights in Air Midwest's program and in AC 120-27C. For example, FAA Notice 8400.40, which was issued less than 3 weeks after the flight 5481 accident, required 14 CFR Part 121 air carriers with 10- to 19-passenger seat airplanes and average weight programs (including Air Midwest) to survey passenger and baggage weights. The survey results showed that the average adult passenger, average carry-on baggage, and average checked baggage weights were greater than the average weights included in AC 120-27C by almost 21, 6, and 4 pounds, respectively. As a result, all 15 operators that were required to participate in the survey had to adjust the weights in one or more categories of their average weight program by 5 to 25 percent.[27]

It is very likely that, if the FAA had conducted such a survey in 2001 before approving Air Midwest's weight and balance program, the FAA could have easily discovered that the average weight assumptions in its weight and balance program guidance were flawed. Thus, the Safety Board concludes that the FAA's average weight assumptions in AC 120-27C, "Aircraft Weight and Balance Control," were not correct.

As demonstrated by the results of the FAA Notice 8400.40 survey, periodic sampling can easily identify and track changing trends in passenger or baggage weights. Periodic sampling of passenger and baggage weights can also identify and track regional, seasonal, or passenger demographic variances that may result in loadings that are significantly different from those based on average weights. In addition, periodic sampling can identify and track those aircraft or routes that carry passengers or baggage with weights that are significantly different from the average weights. Analysis of the survey results would provide a sound basis for future adjustments to average weights so that they would more closely reflect actual passenger and baggage loads.

The Safety Board concludes that periodic sampling of passenger and baggage weights would determine whether air carrier average weight programs were accurately representing passenger and baggage loads. Therefore, the Safety Board believes that, unless an actual weight program is developed and implemented, the FAA should establish a weight and balance program that requires 14 CFR Part 121 air carriers to periodically sample passenger and baggage weights and determine appropriate statistical distribution characteristics for regional, seasonal, demographic, aircraft, and route variances. In addition, the Safety Board believes that the FAA should establish a program to periodically review 14 CFR Part 121 air carrier weight and balance data to ensure that regional, seasonal, demographic, aircraft, and route trends among carriers are valid. Further, the Safety Board believes that the FAA should require 14 CFR Part 121 air

[27] Recent international survey data substantiate the trend of increasing passenger and carry-on baggage weights.

carriers to retain all survey data and products, as well as documentation of the methodology used to justify their average weight programs, and should audit these data as necessary.

Use of Average Weights

The Safety Board is concerned that air carrier average weight programs do not generally account for variances in passenger and baggage weights and weight distribution.[28] As a result, it is possible for a flight crew to mistakenly determine that an airplane is within its certified weight and CG envelope when the airplane is actually outside the envelope. The use of a predetermined average weight assumes that, although an individual passenger or bag may weigh more or less than the average weight, the variance will be appropriately distributed throughout an aircraft. However, deviations from the average weight value and average weight distribution can negatively affect an aircraft's CG if the heavier passengers and baggage are not appropriately distributed. Further, it is possible that some airplane types may be more susceptible than others to errors in CG loading. Specifically, the FAA air safety investigator from the Air Carrier Operations Branch stated, during public hearing testimony, "aircraft that have a larger seating capacity have the ability to spread the deviation from standard across a larger population. So…aircraft with…a smaller seating capacity could have…a greater chance for error than a larger aircraft."

Several factors besides aircraft type (including region of travel, season, passenger mix, number of bags, and amount of personal items) can influence the accuracy of average weight assumptions, and no current method of calculating passenger and baggage weights can ensure, with 100-percent certainty, that an airplane's loading will not exceed its certified weight and CG limits. An airplane's susceptibility of operating outside its weight and CG limits could be minimized if additional safety margins were determined and factored into weight and balance calculations.

The Safety Board concludes that the current safety margins in air carrier average weight and balance programs do not ensure that aircraft will be loaded within their manufacturer-certified and FAA-approved weight and CG envelope. Therefore, the Safety Board believes that the FAA should require 14 CFR Part 121 air carriers that use average weight and balance programs to develop and implement weight and CG safety margins to account for individual passenger and baggage variances.

[28] The average passenger, checked baggage, and carry-on baggage weights suggested by the FAA in AC 120-27C also do not consider weight variances and weight distribution variances.

Technological Advances

As a result of its findings from the August 7, 1997, Fine Airlines flight 101 accident,[29] the Safety Board issued Safety Recommendation A-98-49 in July 1998. Safety Recommendation A-98-49 asked the FAA to evaluate and, if warranted, require the installation of a system that provides a cockpit display of weight and balance information for transport-category cargo airplanes. One such system at the time was the Sum Total Aft and Nose system (commonly referred to as the "STAN" system), which derived weight and balance information from pressure transducers on the main gear and nose gear shock struts. The FAA evaluated onboard weight and balance systems and found that the existing systems could not meet the reliability and accuracy standards for a mandatory system (because of unresolved operational challenges such as wind, ramp slope, oleo stiction, low hydraulic pressure, and asymmetrical gear loads). Thus, the Safety Board classified Safety Recommendation A-98-49 "Closed—Acceptable Action."

The Safety Board is aware of current efforts in private industry to develop aircraft onboard weight and balance systems. In fact, the FAA's Aircraft Weight and Balance Control Program Aviation Rulemaking Committee[30] is considering adding onboard weight and balance system certification specifications to the guidance in the next version of AC 120-27 (AC 120-27D). The Board is also aware of efforts to develop systems to rapidly weigh and automatically track passenger and baggage weight and location data as passengers board aircraft. Technological advances in hand-held computing devices, wireless bar code scanners, inventory tracking algorithms, and overnight package shipping logistics suggest that it may be feasible to compile actual weight data and account for the weight location, enabling a rapid and reliable calculation of actual aircraft weight and balance.

The Safety Board concludes that technology may enable air carriers to accurately determine weight and effectively control balance while maintaining operational efficiency. Therefore, the Safety Board believes that FAA should conduct or sponsor research to develop systems that are capable of delivering actual aircraft weight and balance data before flight dispatch. These systems should rapidly provide accurate and reliable weight and balance data. The Safety Board further believes that FAA should promote the use of systems that deliver accurate weight and balance data as a preferred alternative to the use of average weight and balance programs.

[29] For more information, see National Transportation Safety Board, *Uncontrolled Impact With Terrain, Fine Airlines Flight 101, Douglas DC-8-61, N27UA, Miami, Florida, August 7, 1997*, Aircraft Accident Report NTSB/AAR-98/02 (Washington, DC: NTSB, 1998).

[30] The FAA formed the Aircraft Weight and Balance Control Program Aviation Rulemaking Committee after the flight 5481 accident. The committee is composed of government, union, and industry representatives from the aviation community. The FAA plans to consider the committee's advice and recommendations when revising AC 120-27C and other related guidance.

Organizational and Management Factors – Raytheon Aircraft Company

During its investigation into the Air Midwest and Colgan Air accidents and the CommutAir incident, the Safety Board identified several areas in the Beech 1900D AMM (which each operator used as the basis for its maintenance work) that could be improved to help mechanics follow each step completely and accomplish procedures correctly.

Regarding the Air Midwest accident, the elevator cable tension graph in the elevator control system rigging procedure did not contain instructions on how to take a temperature reading, which was needed to determine the tension values at which the cables should be set. Regarding the Colgan Air accident, the elevator trim system rigging procedure showed an incorrect illustration of the forward elevator trim cable drum. This error could have resulted in the incorrect installation of the elevator trim cable and elevator tab operation in the direction opposite of that commanded by the trim wheel. Regarding the CommutAir incident, the Beech 1900D AMM did not contain a procedure for replacing a thrust lever detent pin.[31]

The Safety Board notes that Beech 1900 series airplanes have been in service since 1984 and have accumulated about 11 million flight hours without significant problems with the AMMs.[32] However, the three recent events involving Beech 1900D airplanes raise concerns that the Beech 1900 series AMMs may no longer be adequate in the current air carrier maintenance environment (less experienced mechanics, an increased prevalence of contracting out maintenance work, and an increased number of startup operations).

On December 10, 2003, the President of Raytheon Airline Aviation Services met with the Safety Board to discuss Beech 1900 maintenance initiatives. On December 16, 2003, the Raytheon official sent the Board a facsimile detailing the initiatives the company would be taking to help Beech 1900 operators "achieve the best possible maintenance and safety practices." The facsimile stated, among other things, that Raytheon Airline Aviation Services would be "developing easy-to-follow text and illustrations designed to improve the explanation of certain procedures, including flight control rigging and functional testing, which are then subject to 'validation and verification.'" The facsimile also stated that Raytheon would issue these changes as temporary revisions to its Beech 1900 series AMMs.

Because the three recent events involving Beech 1900D airplanes demonstrated that mechanics for the three operators did not adequately perform their duties, the Safety Board concludes that Beech 1900 mechanics would benefit from using AMMs with more specific

[31] Because the AMM did not contain this procedure, the mechanic used the installation instructions in a Beech 1900D field service kit for "thrust lever, replaceable detent pin." However, the installation instructions did not describe how to remove the thrust lever control assembly from the center pedestal, which is required to replace a thrust lever detent pin. Also, the installation instructions did not provide any references to specific maintenance manual sections or procedures for removing the thrust lever control assembly from the center pedestal.

[32] The Safety Board's accident and incident database included two Beech 1900 events in which inadequate maintenance manual procedures were part of the probable cause. For information about these events, see MIA00IA266 and NYC00IA150 on the Safety Board's Web site.

instructions for critical flight system procedures. Therefore, the Safety Board believes that the FAA should ensure that Raytheon Aircraft Company revises the maintenance procedures for critical flight systems in its Beech 1900, 1900C, and 1900D AMMs to ensure that the procedures can be completely and correctly accomplished.

Cockpit Voice Recorders Installed in Beech 1900 Series Airplanes

Before the flight 5481 accident, Beech 1900 series airplanes had experienced problems with the low signal volume of very high frequency (VHF) radio messages that were recorded by cockpit voice recorders (CVR) installed on the airplanes. As a result, the Safety Board issued Safety Recommendation A-97-36 on May 22, 1997. Safety Recommendation A-97-36 asked the FAA to require the inspection of CVRs aboard Beech 1900 airplanes and ensure that the operator take corrective actions so that the intelligibility of recorded communications was as high as practicable.

Raytheon Aircraft Company issued Service Bulletin (SB) 23-3094, which recommended the incorporation of an improved CVR amplifier and new circuitry for the wiring. Subsequently, the FAA issued AD 2000-20-07, which required that all applicable Beech 1900 airplanes comply with Raytheon's SB. On January 30, 2001, the Safety Board classified Safety Recommendation A-97-36 "Closed—Acceptable Action."

The accident airplane's maintenance records indicated that the actions required by the AD were accomplished on March 3, 2001. However, the volume of the incoming VHF radio messages during the accident flight was extremely low compared with the volume of the audio captured by the flight crew's hot microphones. Because the audio from the captain's, or first officer's, hot microphone was recorded on the same channel as the audio from the VHF radio, the two audio signals could not be isolated from each other on the recording.

On August 29, 2002, the Safety Board issued Safety Recommendation A-02-25 as a result of its longstanding concerns about the availability of CVR information after reportable accidents or incidents. Safety Recommendation A-02-25 asked the FAA to

> Require that all operators of airplanes equipped with a cockpit voice recorder (CVR) test the functionality of the CVR system prior to the first flight of each day, as part of an approved aircraft checklist. This test must be conducted according to procedures provided by the CVR manufacturer and shall include, at a minimum, listening to the recorded signals on each channel to verify that the audio is being recorded properly, is intelligible, and is free from electrical noise or other interference.

On December 12, 2002, the FAA stated current regulations (14 CFR 23.1457 and 25.1457) require CVR equipment to have "an aural or visual means for preflight checking of the recorder for proper operation." The FAA also stated that it would survey current maintenance practices of air carrier and general aviation aircraft to determine if corrections to the operators'

maintenance programs were necessary to ensure expected recorder reliability. On January 16, 2003, the Safety Board stated its concern that that the FAA's maintenance survey would address only one part of the CVR reliability problem. The Board's safety recommendation letter stressed that it was the flight crew's responsibility to check the CVR for proper operation each day before the first flight; consequently, the Board encouraged the FAA to include maintenance procedures and crew checklist operational procedures in its survey.

The Safety Board was concerned that the FAA might have misunderstood the portion of the recommendation concerning a daily test of the equipment. Even though the FAA stated that 14 CFR 23.1457 and 25.1457 required CVR equipment to have "an aural or visual means for preflight checking of the recorder for proper operation," the Board stated that it was unaware of any CVR installations that did not have the ability to monitor the audio using a headphone jack in the cockpit. The Board indicated that the intended minimum for the daily test outlined in the safety recommendation would be similar to the procedures outlined in FAA Order 8300.10, Chapter 143, "Monitor Cockpit Voice Recorders." This chapter states, among other things, to "check all channels to ensure that the quality of the reproduction has not deteriorated below an optimal audible level."[33] The Board urged the FAA to ensure that a similar check is required before the first flight of the day in all aircraft equipped with a CVR. Pending full implementation of this requirement, Safety Recommendation A-02-25 was classified "Open—Acceptable Response."

Because the captain and the first officer's audio panel information was fair to poor quality with respect to the audio captured from the airplane's VHF radio systems, it is possible that important CVR information from flight 5481 might not have been transcribed if the audio information from the captain's and the first officer's hot microphones had not been excellent to good quality. The Safety Board concludes that, because the CVR can be one of the most valuable tools used for accident investigation, reliable daily test procedures are needed to safeguard CVR data. Therefore, the Safety Board reiterates Safety Recommendation A-02-25.

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

> Adopt a program for performing targeted surveillance and increased oversight of maintenance practices at 14 *Code of Federal Regulations* Part 121 air carriers to ensure that maintenance instructions are being followed as written and that maintenance personnel (including, but not limited to, management, quality assurance, tooling, and training personnel, as well as mechanics) are following all steps in the instructions unless authorization has been granted in accordance with the air carrier's maintenance program. (A-04-4)

[33] The Safety Board's letter also cited an example of a required daily check in the FAA's Flight Standards Information Bulletin for Airworthiness 99-04. The bulletin indicated that the Beech 1900C Airplane Flight Manual contained a preflight inspection by the flight crew, which included monitoring the area microphone.

Verify that 14 *Code of Federal Regulations* Part 121 air carriers have procedures in their Continuing Analysis and Surveillance System program for identifying deficiencies and incorporating changes to the carrier's maintenance program and that maintenance personnel for these air carriers (including, but not limited to, management, quality assurance, tooling, and training personnel, as well as mechanics) use these procedures. (A-04-5)

Modify (1) appendix G of 14 *Code of Federal Regulations* (CFR) Part 23 and appendix H of 14 CFR Part 25 and (2) 14 CFR 121.369 to require that the Instructions for Continued Airworthiness and air carrier maintenance manuals, respectively, include a complete functional check at the end of maintenance for each critical flight system. (A-04-6)

Require manufacturers of aircraft operated under 14 *Code of Federal Regulations* Part 121 to identify appropriate procedures for a complete functional check of each critical flight system; determine which maintenance procedures should be followed by such functional checks; and modify their existing maintenance manuals, if necessary, so that they contain procedures at the end of maintenance for a complete functional check of each critical flight system. (A-04-7)

Require 14 *Code of Federal Regulations* Part 121 air carriers to modify their existing maintenance manuals, if necessary, so that they contain procedures at the end of maintenance for a complete functional check of each critical flight system. (A-04-8)

Prohibit inspectors from performing required inspection item inspections on any maintenance task for which the inspector provided on-the-job training to the mechanic who accomplished the task. (A-04-9)

Require 14 *Code of Federal Regulations* Part 121 air carriers that use contractors to perform required inspection item (RII) maintenance tasks and inspections to have air carrier personnel who are physically present when a substantial amount of the RII planning, tasking, maintenance work, and inspections are performed and are readily available when they are not physically present and who ensure that the processes and procedures used by contractors to perform RII maintenance tasks and inspections are the same as those used by air carrier maintenance personnel. (A-04-10)

Develop detailed on-the-job (OJT) training requirements for 14 *Code of Federal Regulations* (CFR) Part 121 air carriers that rely on OJT as a maintenance training method. These requirements should include, but not be limited to, best practices, procedures, and methods for accomplishment and administration of this training. Ensure that these OJT requirements are incorporated into 14 CFR Part 121 air carrier maintenance training programs. (A-04-11)

Audit training records for personnel who are currently performing maintenance on Air Midwest airplanes to verify that the training was properly accomplished in accordance with the company's Maintenance Procedures Manual and Maintenance Training Manual. (A-04-12)

Require 14 *Code of Federal Regulations* Part 121 air carriers to implement a program in which carriers and aircraft manufacturers review all work card and maintenance manual instructions for critical flight systems and ensure the accuracy and usability of these instructions so that they are appropriate to the level of training of the mechanics performing the work. (A-04-13)

Include the Continuing Analysis and Surveillance System guidance from Advisory Circular (AC) 120-16D, "Continuing Airworthiness Maintenance Programs," and AC 120-79, "Developing and Implementing a Continuing Analysis Surveillance System," in Federal Aviation Administration Order 8300.10, *Airworthiness Inspector's Handbook*. (A-04-14)

Require that all 14 *Code of Federal Regulations* Part 121 air carrier maintenance training programs be approved. (A-04-15)

Require that 14 *Code of Federal Regulations* Part 121 air carriers implement comprehensive human factors programs to reduce the likelihood of human error in aviation maintenance. (A-04-16)

Identify those situations that would require the use of actual instead of average weights in weight and balance computations and incorporate this information into Advisory Circular 120-27, "Aircraft Weight and Balance Control." (A-04-17)

Unless an actual weight program is developed and implemented, establish a weight and balance program that requires 14 *Code of Federal Regulations* Part 121 air carriers to periodically sample passenger and baggage weights and determine appropriate statistical distribution characteristics for regional, seasonal, demographic, aircraft, and route variances. (A-04-18)

Establish a program to periodically review 14 *Code of Federal Regulations* Part 121 air carrier weight and balance data to ensure that regional, seasonal, demographic, aircraft, and route trends among carriers are valid. (A-04-19)

Require 14 *Code of Federal Regulations* Part 121 air carriers to retain all survey data and products, as well as documentation of the methodology used to justify their average weight programs, and audit these data as necessary. (A-04-20)

Require 14 *Code of Federal Regulations* Part 121 air carriers that use average weight and balance programs to develop and implement weight and center of gravity safety margins to account for individual passenger and baggage variances. (A-04-21)

Conduct or sponsor research to develop systems that are capable of delivering actual aircraft weight and balance data before flight dispatch. These systems should rapidly provide accurate and reliable weight and balance data. (A-04-22)

Promote the use of systems that deliver accurate weight and balance data as a preferred alternative to the use of average weight and balance programs. (A-04-23)

Ensure that Raytheon Aircraft Company revises the maintenance procedures for critical flight systems in its Beech 1900, 1900C, and 1900D Airliner Maintenance Manuals to ensure that the procedures can be completely and correctly accomplished. (A-04-24)

In addition, the Safety Board reiterates the following recommendation to the Federal Aviation Administration:

Require that all operators of airplanes equipped with a cockpit voice recorder (CVR) test the functionality of the CVR system prior to the first flight of each day, as part of an approved aircraft checklist. This test must be conducted according to procedures provided by the CVR manufacturer and shall include, at a minimum, listening to the recorded signals on each channel to verify that the audio is being recorded properly, is intelligible, and is free from electrical noise or other interference. (A-02-25)

Chairman ENGLEMAN CONNERS, Vice Chairman ROSENKER, and Members GOGLIA, CARMODY, and HEALING concurred in these recommendations.

By: Ellen Engleman Conners
Chairman