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Misrigged Elevator and Aft Loading Cause Loss of Control of Raytheon Beech 1900D

Limited nose-down elevator travel and an excessive aft center of gravity rendered the twin-turboprop airplane uncontrollable in pitch on takeoff from Charlotte, North Carolina, U.S. The accident report cited incorrect rigging of the elevator-control system and deficiencies in maintenance oversight and in calculation of passenger weights and baggage weights.

FSF Editorial Staff

About 0847 local time on Jan. 8, 2003, a Raytheon Beech 1900D being operated by Air Midwest as Flight 5481 struck a maintenance hangar and terrain during takeoff in daylight visual meteorological conditions from Charlotte–Douglas International Airport in Charlotte, North Carolina, U.S. The 21 occupants were killed, and one person on the ground received minor injuries.

The U.S. National Transportation Safety Board (NTSB) said, in its final report, that the probable cause of the accident was "the airplane's loss of pitch control during takeoff [that] resulted from the incorrect rigging of the elevator-control system [at the airline's maintenance station in Huntington, West Virginia], compounded by the airplane's aft center of gravity [CG], which was substantially aft of the certified aft limit."

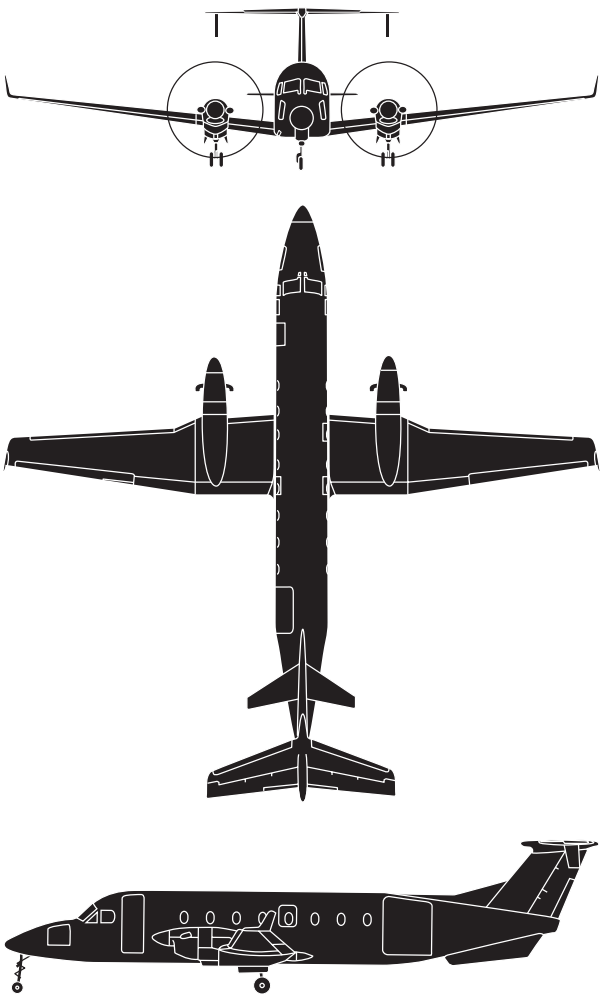
The report said, "Contributing to the accident were:

- "Air Midwest's lack of oversight of the work being performed at the Huntington, West Virginia, maintenance station;
- "Air Midwest's maintenance procedures and documentation;
- "Air Midwest's weight-and-balance program at the time of the accident;
- "The Raytheon Aerospace quality-assurance inspector's failure to detect the incorrect rigging of the elevator-control system [Raytheon Aerospace was a maintenance contractor for the airline];
- "The [U.S.] Federal Aviation Administration's [FAA's] average weight assumptions in its weight-and-balance program guidance at the time of the accident; and,
- "The FAA's lack of oversight of Air Midwest's maintenance program and its weight-and-balance program."

The accident airplane, manufactured and delivered to Air Midwest in 1996, had 15,003 flight hours and 21,332 cycles (each cycle comprises one takeoff and landing). During the two days preceding the accident, maintenance was performed on the airplane at the Huntington station.

"Air Midwest contracted with Raytheon Aerospace to provide mechanics, quality-assurance inspectors and a site manager

for the [Huntington] maintenance station," the report said. "[Raytheon Aerospace] contracted with Structural Modification and Repair Technicians, Inc. (SMART) to supply the mechanic work force."



Raytheon Beech 1900D

The Beech 1900D is a twin-turboprop regional transport that entered service in 1991 and currently is manufactured by Raytheon Aircraft Co. The airplane is a derivative of the Beech 1900, which first flew in 1982. The 1900D has a flat floor, a maximum cabin height of 5.9 feet (1.8 meters) and 28.5 percent more cabin volume than its predecessor, the Beech 1900C. Standard accommodation is for two flight crew members and 19 passengers.

The airplane is powered by two Pratt & Whitney Canada PT6A-67D engines, each flat rated at 1,279 shaft horsepower (954 kilowatts), and Hartzell four-blade, composite propellers. Maximum takeoff weight is 17,120 pounds (7,766 kilograms). Maximum landing weight is 16,765 pounds (7,605 kilograms). Maximum cruising speed at 15,000 pounds (6,818 kilograms) gross weight and 25,000 feet altitude is 274 knots. Stalling speed at maximum takeoff weight with flaps retracted is 101 knots.♦

Source: *Jane's All the World's Aircraft* and Raytheon Aircraft Co.

Air Midwest's regional site manager worked the day shift at the Huntington station and was not present when the maintenance was performed on the accident airplane. The maintenance included visual inspections and servicing of the airplane's major components, and one phase of a "detail six" (D6) maintenance check. The Air Midwest maintenance program included six D6 check phases, with a different phase conducted every 200 flight hours. The phase conducted during the two days preceding the accident comprised checks of the airplane's elevator, rudder and trim tabs.

On the night of Jan. 6, 2003, the quality-assurance inspector at the Huntington station was providing on-the-job training (OJT) to two SMART maintenance technicians (mechanics) who previously had not performed a complete D6 maintenance check. The quality-assurance inspector assigned one of the mechanics — who had performed rigging work on de Havilland Dash 8s — to check the tension of the elevator-control cables.

"[The] quality-assurance inspector, who was providing the mechanic's OJT, stated that he did not think he needed to closely supervise the mechanic because of his previous flight-control-rigging experience," the report said.

The D6 inspection procedures checklist (work card) indicated that cable tension was to be checked according to the elevator-control-system rigging procedure in the *Beech 1900D Airliner Maintenance Manual*. The report said that although interviews of officials of Air Midwest and Raytheon Aircraft Co. indicated that the entire elevator-control-system rigging procedure must be performed when cable-tension adjustments are made, neither the D6 work card nor the Beech 1900D maintenance manual "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."

The mechanic omitted several steps in the published rigging procedure; some of the steps were omitted with the quality-assurance inspector's concurrence.

"[The quality-assurance] 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 report said.

As a result of the omitted steps, the elevator-control system was incorrectly rigged during the D6 maintenance check, and the incorrect rigging restricted the airplane's elevator travel to seven degrees nose-down — about one-half the downward travel specified by the airplane manufacturer (i.e., 14 degrees to 15 degrees nose-down).

"Examination of the accident airplane's pitch-control-cable turnbuckles as found in the wreckage revealed that the AND [airplane-nose-down] turnbuckle, which measured 7.30 inches

[18.54 centimeters] in length, was extended 1.76 inches [4.47 centimeters] more than the ANU [airplane nose-up] turnbuckle, which measured 5.54 inches [14.07 centimeters] in length," the report said. "However, according to data from Air Midwest's postaccident survey of its entire fleet of 42 Beech 1900D airplanes, the AND turnbuckle was extended, on average, only 0.04 inch [0.10 centimeter] less than the ANU turnbuckle.

"Ground tests showed that turnbuckles adjusted to the lengths of those found in the wreckage would result in limited downward elevator travel. … Adjustments to the cable turnbuckles (and possibly other adjustable components) during maintenance resulted in FDR [flight data recorder] measurements that showed a nine-degree AND loss of travel, which restricted the accident airplane's elevator travel to seven degrees AND."

The report said that the quality-assurance inspector did not provide adequate OJT to the mechanic who adjusted the elevator-control system.

"Insufficient training and supervision resulted in the mechanic making mistakes that led to the incorrect rigging and the restricted downward elevator travel," the report said. "If the quality-assurance inspector had provided better training and supervision, the likelihood of such errors would have been minimized."

"Insufficient training and supervision resulted in the mechanic making mistakes that led to the incorrect rigging and the restricted downward elevator travel."

The postmaintenance checks performed by the quality-assurance inspector and the mechanic did not include calibration of the pitch-position potentiometer, which is included in the rigging procedure. The report said that the misrigging likely would have been found if this check had been performed.

The rigging procedure did not include a functional check, in which a mechanic positioned at the tail of the airplane uses a device to measure elevator travel while another mechanic moves the control column full forward and full aft. Raytheon Aircraft Co. on Feb. 12, 2003, issued a revised elevator-control-system-rigging procedure that included a postmaintenance functional check.

The report said that, except for the elevator-control system, the accident airplane was properly maintained.

After the airplane was released from maintenance on Jan. 7, it was flown from Huntington to Charlotte. The first officer on that flight told the accident first officer that "everything was normal" and that "it was a good-flying airplane." The accident flight crew conducted six flights in the airplane from 1340 to 2045. Another crew then flew the airplane to Lynchburg, Virginia, and returned to Charlotte the next morning.

"According to postaccident interviews, neither the captain nor the first officer on those two flight legs noticed anything unusual about the airplane," the report said.

Flight 5481 was a regularly scheduled passenger flight from Charlotte to Greenville–Spartanburg (South Carolina) International Airport.

The captain, 25, had an airline transport pilot certificate and approximately 2,790 flight hours, including 1,100 flight hours as a Beech 1900D pilot-in-command. She was a flight instructor and flight-school supervisor before being hired by Air Midwest in March 2000. She earned a Beech 1900D type rating in March 2001.

"In postaccident interviews, Air Midwest pilots who had flown with the captain made favorable comments about her piloting skills," the report said. "A check airman stated that the captain had no difficulties during upgrade training and that she demonstrated very good knowledge of the airplane's systems and very good judgment. Another check airman described the captain as one of the better company pilots and stated that she made very good decisions about flying.

"First officers stated that the captain was a thorough and methodical pilot who controlled the airplane well and involved them with the flight by asking for [their] opinions and letting them review paperwork."

The first officer, 27, had a commercial pilot certificate and approximately 1,096 flight hours, including 706 flight hours as a Beech 1900D second-in-command. Before being hired by the airline in May 2001, he was enrolled in a college pilot-development program for Mesa Airlines, parent company of Air Midwest.

"In postaccident interviews, Air Midwest pilots who had flown with the first officer made favorable comments about his piloting skills," the report said. "Pilots described the first officer as a talented and very precise pilot with good attention to detail and good communication skills. Pilots also stated that the first officer possessed good situational awareness and good knowledge of the Beech 1900D."

The first officer did not detect the elevator's misrigging during his preflight inspection of the airplane.

"The only visible sign of the misrig during the first officer's external preflight inspection would have been a change in the elevator resting position," the report said. "The normal elevator resting position is between 14 degrees and 15 degrees [nose-down]; after the misrig, the elevator resting position was about seven degrees [nose-down]. Because the horizontal stabilizer on a parked Beech 1900D is located about 15 feet [five meters]

above the ground, it would be difficult to detect the change in the elevator resting position from the ground."

Air Midwest used an FAA-approved weight-and-balance-control program that allowed the use of either actual weights or average weights of passengers and baggage. The average weights used by Air Midwest conformed with guidance in FAA Advisory Circular (AC) 120-27C, *Aircraft Weight and Balance Control*. The circular recommended the use of average weights derived from a survey of actual passenger weights and baggage weights or the use of the following average weights: 180 pounds (82 kilograms) for passengers during spring and summer months; 185 pounds (84 kilograms) for passengers during fall and winter months; 20 pounds (nine kilograms) for carry-on baggage; and 25 pounds (11 kilograms) for checked baggage.

The report said that the average weights used by Air Midwest were approved but not validated by an FAA principal maintenance inspector. The approved average weights used by the airline were: 170 pounds (77 kilograms) for adults in summer; 175 pounds (79 kilograms) for adults in winter; 80 pounds (36 kilograms) for children aged two through 12; 10 pounds (five kilograms) for carry-on items; and 25 pounds for carry-on items that did not fit either under a passenger seat or in the cabin coat closet and were placed in the aft cargo compartment.

The flight crew used average weights for the passengers and baggage when they completed a load-manifest form for the flight.

Maximum takeoff weight of the Beech 1900D is 17,120 pounds (7,766 kilograms), and the aft CG limit is 40 percent mean aerodynamic chord (MAC). The flight crew calculated that the airplane's takeoff weight was 17,028 pounds (7,724 kilograms) and the CG was 37.8 percent MAC.

The investigation determined that the actual takeoff weight was 17,700 pounds, plus or minus 200 pounds (8,029 kilograms, plus or minus 91 kilograms) and that the CG was 45.5 percent MAC, plus or minus 2 percent MAC.

One of the two ramp agents who handled the baggage told investigators that two of the checked bags were heavy; he estimated that each bag weighed between 70 pounds and 80 pounds (32 kilograms and 36 kilograms).

"The ramp agent also stated that he told the captain that some of the bags were heavy, although they were not marked as such," the report said. "According to the ramp agent, the captain indicated that the bags were fine because a child would be on board, which would allow for the extra baggage weight."

The crew used a value of 175 pounds, rather than 80 pounds, for the 12-year-old child when they calculated the airplane's weight and balance.

The report said that gate agents had not attached a "heavy bag tag" to the two heavy bags, to indicate that they weighed between 70 pounds and 100 pounds (45 kilograms), and the load report did not identify the bags as being overweight.

"As a result, the flight crew was not required to account for the extra weight of the reportedly heavy bags on the load manifest form," the report said.

Investigators found that four of the 31 bags aboard the airplane weighed more than 50 pounds (23 kilograms) and that the average weight of the passengers (16 males and three females) was 185 pounds.

Although AC 120-27C says that standard average passenger weights cannot be used when passenger composition is different than 60 percent male and 40 percent female, "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 [passenger weights] rather than average passenger weights."

The report said that the changes resulting from the misrigging of the elevator would not have been conspicuous to the flight crew.

The crew's weight-and-balance calculations also included a taxi fuel-consumption value of 220 pounds (100 kilograms), rather than the airline's standard of 110 pounds (50 kilograms). The report said that if the calculations had included the actual weights of the two overweight bags and a taxi fuel-consumption value of 110 pounds, the calculated gross weight would have exceeded the airplane's takeoff weight limit.

The airplane departed from the gate on time at 0830. About five minutes later, the captain (the pilot flying) conducted an elevator-control check as part of the "Taxi" checklist. Data recorded by the FDR indicated that during the check, the elevator was moved from full nose-up to seven degrees nose-down.

The captain said, "Flight controls, free and correct."

The report said that the changes resulting from the misrigging of the elevator would not have been conspicuous to the flight crew. During the investigation, three pilots with Beech 1900D type ratings conducted control sweeps (i.e., moved the control column full forward and full aft) in a test airplane with the elevator rigged according to specifications and again with the elevator misrigged similar to the accident airplane.

"The [test] pilots did not report any noticeable change in the feel or position of the control wheel between the two sets of control sweeps," the report said.

At 0846, air traffic control (ATC) cleared the crew to take off on Runway 18R and told them to turn right to a heading of 230 degrees after takeoff.

FDR data indicated that the airplane pitched nose-up after lift-off although the captain applied forward pressure on her control column and nose-down trim.

Soon after the landing gear were retracted, the cockpit voice recorder (CVR) recorded the first officer saying "wuh," and the captain saying, "oh … help me." The airplane was about 90 feet above the ground, and airspeed was 139 knots. FDR data indicated that the airplane's pitch attitude was 20 degrees nose-up.

At 0847:04, the captain said, "You got it?" FDR data indicated that both pilots were pushing forcefully on their control columns.

"During the next eight seconds, the CVR recorded multiple statements and sounds [grunts and exhalations of breath] from both flight crewmembers associated with their efforts to push the airplane's nose down," the report said.

Postaccident studies in a flight simulator indicated that an elevator position of 9.5 degrees nose-down would have been required to recover from the initial airplane upset.

At 0847:09, the CVR recorded a sound similar to a change in the noise produced by the engines and propellers. About one second later, the CVR recorded the sound of the stall-warning horn, which continued for six seconds.

At 0847:11, the captain said, "Push the nose down."

The airplane's nose-up pitch attitude reached a maximum of 54 degrees at 0847:13. The captain told ATC, "We have an emergency for Air Midwest fifty-four eighty-one."

"About 0847:18, the airplane's pitch attitude decreased through zero degrees and the elevator position began to move [nose-up]," the report said. "By 0847:19, the airplane was about 1,150 feet above ground level, and the FDR recorded a maximum left roll of 127 degrees and a minimum airspeed of 31 knots. About one second later, the FDR recorded a pitch attitude of 42 degrees [nose-down]."

The captain told the first officer, "Pull the power back."

Elevator position reached full nose-up at 0847:21. The airplane's pitch attitude was 39 degrees nose-down, and the stall-warning horn sounded and continued until the end of the CVR recording about six seconds later.

"About 0847:22, the airplane's roll attitude stabilized at about 20 degrees left-wing-down; the pitch attitude began to increase; and the elevator position moved in [a nose-down] direction," the report said. "About one second later, the elevator position began moving in the [nose-up] direction."

About 0847:24, the airplane rolled right through wings-level. Two seconds later, the FDR recorded a maximum right roll of 68 degrees and a maximum vertical acceleration of 1.9 g (i.e., 1.9 times standard gravitational acceleration).

"About the same time, the captain stated, 'Oh my god, ah,' and the first officer stated something similar to, 'Uh, uh, god, ah [expletive],'" the report said.

The CVR recording ended at 0847:28. Among the last values recorded by the FDR were a pitch attitude of 47 degrees nose-down, a roll attitude of 66 degrees right and a control-column position corresponding to full nose-up elevator travel.

If the airplane's weight and CG had been within limits, the airplane might have been controllable with elevator travel restricted to half the normal nose-down travel.

"The airplane struck a US Airways maintenance hangar on [airport] property and came to rest about 1,650 feet [503 meters] east of the Runway 18R centerline and about 7,600 feet [2,318 meters] beyond the Runway 18R threshold," the report said.

A postaccident fire destroyed most of the airplane structure. Autopsy reports indicated that the cause of death for all the occupants was "multiple blunt-force injuries due to the airplane crash."

"The accident was not survivable for the airplane occupants because they were subjected to impact forces that exceeded the limits of human tolerance," the report said.

The report said that if the airplane's weight and CG had been within limits, the airplane might have been controllable with elevator travel restricted to half the normal nose-down travel.

"The restricted elevator travel alone and the aft CG alone would not have been sufficient to cause the uncontrolled pitch-up that led to the Flight 5481 accident," the report said. "[The] 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."

On Jan. 27, 2003, FAA issued emergency airworthiness directive (AD) 2003-03-18, requiring operators of Beech 1900 models to inspect the elevator-control system and to verify full elevator travel.

In late January 2003, FAA required air carriers that used average-weight programs for 10-seat airplanes to 19-seat airplanes to survey passenger weights and baggage weights. The survey results showed that, compared to the average weights included in AC 120-27C, average adult passengers were 21 pounds (10 kilograms) heavier, average carry-on bags were six pounds (three kilograms) heavier and average checked bags were four pounds (two kilograms) heavier.

"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 programs by 5 [percent] to 25 percent," the report said.

On May 12, 2003, FAA required all U.S. commercial aircraft operators either to revise their average-weight programs — by adding 10 pounds per passenger and five pounds (two kilograms) for checked baggage — or to conduct an average-weight survey.

An aircraft weight-and-balance-control program aviation rule-making committee, which held its first meeting in August 2003, issued draft revisions to AC 120-27C on Jan. 30, 2004. The report said that FAA expects to solicit public comment on proposed revisions to the AC at the end of 2004.

The report said that unlike training programs for airline pilots, flight attendants and other personnel, the training programs for maintenance technicians do not require formal approval by FAA.

"FAA staff indicated that managing the content of, and ensuring compliance with, air carrier training programs that are not approved … can be more difficult than for programs that are approved," the report said.

The report said that the FAA principal maintenance inspector assigned to Air Midwest had identified several deficiencies in the airline's maintenance training program during the two years preceding the accident but that FAA had not "aggressively pursued [improvements to] the airline's maintenance training program."

"It is critical that proper FAA oversight is provided for every air carrier maintenance training program to ensure that any program deficiencies are identified," the report said. "It is even more critical for the FAA to forcefully pursue maintenance training program improvements when deficiencies have been identified."

In April 2003, FAA published AC 120-79, *Developing and Implementing a Continuing Analysis Surveillance System*. The report said that the AC is a comprehensive guide for the development of continuing maintenance analysis and surveillance systems but that the information was not disseminated to air carrier inspectors in FAA Order 8300.10, *Airworthiness Inspector's Handbook*.

Based on the findings of the investigation, NTSB made the following recommendations to FAA:

- "Adopt a program for performing targeted surveillance and increased oversight of maintenance practices at [U.S. Federal Aviation 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;

- "Verify that [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;

- "Modify Appendix G of [Part 23], Appendix H of [Part 25] and [Part] 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;

- "Require manufacturers of aircraft operated under [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;

- "Require [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;

- "Prohibit inspectors from performing required inspection item inspections on any maintenance task for which the inspector provided [OJT] to the mechanic who accomplished the task;

- "Require [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;

- "Develop detailed [OJT] training requirements for [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 [Part 121] air carrier maintenance training programs;

- "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*;

- "Require [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;

- "Include the continuing analysis and surveillance system guidance from [AC] 120-16D, *Continuing Airworthiness Maintenance Programs*, and AC 120-79 … in [the] *Airworthiness Inspector's Handbook*;

- "Require that all [Part 121] air carrier maintenance training programs be approved;

- "Require that [Part 121] air carriers implement comprehensive human factors programs to reduce the likelihood of human error in aviation maintenance;

- "Identify those situations that would require the use of actual [weights] instead of average weights in weight-and-balance computations and incorporate this information into [AC] 120-27D;

- "Unless an actual-weight program is developed and implemented, establish a weight-and-balance program that requires [Part 121] air carriers to periodically sample passenger [weights] and baggage weights, and determine appropriate statistical distribution characteristics for regional, seasonal, demographic, aircraft and route variances;

- "Establish a program to periodically review [Part 121] air carrier weight-and-balance data to ensure that regional, seasonal, demographic, aircraft and route trends among carriers are valid;

- "Require [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;

- "Require [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 [variances] and baggage variances;

- "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;

- "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; [and,]

- "Ensure that Raytheon Aircraft Co. 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."

[NTSB issued the recommendations on March 5, 2004. As of May 4, 2004, NTSB was awaiting response to the recommendations from FAA.]♦

[FSF editorial note: This article, except where specifically noted, is based on U.S. National Transportation Safety Board Aircraft Accident Report NTSB/AAR-04/01: *Loss of Pitch Control During Takeoff; Air Midwest Flight 5481; Raytheon (Beechcraft) 1900D, N233YV; Charlotte, North Carolina; January 8, 2003*. The 214-page report contains illustrations and appendixes.]

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