National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: February 18, 1997

In reply refer to: A-97-3 through -10

Honorable Barry L. Valentine
Acting Administrator
Federal Aviation Administration
Washington, D.C. 20591

On February 19, 1996, at 0902 central standard time, Continental Airlines (COA) flight 1943, a Douglas DC-9-32, N10556, landed wheels up on runway 27 at the Houston Intercontinental Airport, Houston, Texas. The airplane slid 6,850 feet before coming to rest in the grass about 140 feet left of the runway centerline. The cabin began to fill with smoke, and the captain ordered the evacuation of the airplane. There were 82 passengers, 2 flightcrew members, and 3 flight attendants aboard the airplane. No fatalities or serious injuries occurred; 12 minor injuries to passengers were reported. The airplane sustained substantial damage to its lower fuselage. The regularly scheduled passenger flight was operating under Title 14 Code of Federal Regulations (CFR) Part 121 and had originated from Washington National Airport (DCA) about 3 hours before the accident. An instrument flight rules flight plan had been filed; however, visual meteorological conditions prevailed for the landing in Houston.

The National Transportation Safety Board determined that the probable cause of this accident was the captain's decision to continue the approach contrary to COA standard operating procedures that mandate a go-around when an approach is unstabilized below 500 feet or a ground proximity warning system alert continues below 200 feet above field elevation (AFE). The following factors contributed to the accident: (1) the flightcrew's failure to properly complete the in-range checklist, which resulted in a lack of hydraulic pressure to lower the landing gear and deploy the flaps; (2) the flightcrew's failure to perform the landing checklist and confirm that the landing gear was extended; (3) the inadequate remedial actions by COA to ensure adherence to standard operating procedures; and (4) the Federal Aviation Administration's (FAA) inadequate oversight of COA to ensure adherence to standard operating procedures.[1]

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[1] For more detailed information, read Aircraft Accident Report—"Continental Airlines Flight 1943, Douglas DC-9-32, N10556, Wheels-up Landing at Houston, Texas, February 19, 1996" (NTSB/AAR-97/01)

Checklist Design

Fifteen minutes before landing, as the airplane descended through 19,000 feet, the captain omitted one item on the in-range checklist. The omitted item, "Hydraulics - ON & HI, CHECKED," would have enabled the high pressure configuration of the hydraulic system, thereby providing pressure to operate the flaps and landing gear. Three steps were required to complete this checklist item: movement of the AUX and ALT pump switches from "OFF" to "ON," movement of the left and right engine-driven hydraulic pump switches from "LOW" to "HI," and confirmation that system pressures were between 2,800 and 3,100 pounds per square inch (psi).

The Safety Board found no evidence indicating that the captain was interrupted or distracted during the performance of the in-range checklist, that the omitted checklist item was obscured, or that the captain believed the first officer would configure the hydraulic system. The Safety Board was unable to determine the specific reason for the captain's omission of the "Hydraulics" item on the in-range checklist.

The Safety Board is concerned that the normal in-flight operating procedure for the DC-9 hydraulic system deactivates (or, in the case of the MD-80, impairs the operation of) certain hydraulic components, including the landing gear and the flaps, without providing an overt signal to the flightcrew of the non-functional status of those components. If the hydraulic system is not configured properly during performance of the in-range checklist, the error can initially only be determined by direct observation of the hydraulic pump switches and pressure gauges. Because the flaps and landing gear are not typically extended until the later stages of an approach, the next opportunity for the flightcrew to detect such an error occurs during a period of higher workload when there is less time for problem diagnosis.

A February 1995 Aviation Safety Reporting System report relevant to this accident and statements by other DC-9 pilots indicate that failure to configure the hydraulic system for landing is not an uncommon occurrence. A review of checklists from several DC-9 and MD-80 operators revealed that none of the checklists, including the Douglas Aircraft Company's checklist, emphasize the importance of the "Hydraulics" item by placing it as the first item on the in-range checklist or requiring mandatory cross-check of the item by both pilots. Further, the item requires only an "ON & HI, CHECKED" response to the challenge and does not require verbal notation of the pressure values. National Aeronautics Space Administration (NASA)-sponsored research on checklist design[2] indicates that critical items should be placed first on a checklist because the probability of successfully accomplishing the first items on a checklist is the highest. In addition, this research indicates that errors in checklist execution can be reduced by designing checklists that incorporate redundancy through requiring cross-check of items by both pilots, and that reduce ambiguity by requiring verbal responses stating the actual value of an item.

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[2] Degani, A. & Weiner, E. Human Factors of Flight-Deck Checklists: The Normal Checklist, NASA Contractor Report 177549, May, 1990.

The Safety Board concludes that the "Hydraulics" item is placed too low on the in-range checklist, rendering it vulnerable to omission. Therefore, the Safety Board believes that the FAA should require all DC-9 and MD-80 operators with the "HI, LOW, OFF" hydraulic switch configuration to revise their checklists to emphasize the importance of the "Hydraulics" item by placing it as the first item on the in-range checklist (or equivalent), and requiring that both pilots verbally verify hydraulic pump switch settings and system pressures.

Improper Hydraulic System Configuration

The flightcrew of flight 1943, consistent with other DC-9 pilots who have reported failing to properly configure the hydraulic system, detected a problem with flap deployment when the airplane did not respond with pitch and speed changes as flaps were selected to 15° and beyond. However, this crew did not recognize that the failure of the flaps to deploy was a symptom of improper hydraulic system configuration. Neither the captain nor the first officer recalled events concerning improper hydraulic system configuration in his previous DC-9 experience and, therefore, did not possess firsthand knowledge to help recognize that the symptom he was experiencing was the result of this error.

In addition, the Safety Board's review of the information provided by COA to its pilots concerning the DC-9 hydraulic system revealed that the flight manual and training materials do not explicitly state that if the pumps are not switched to "HI," the landing gear will not extend and the flaps will not deploy. The Safety Board concludes that the pilots' lack of previous exposure, either through training or during line operations, to the consequences of improper hydraulic system configuration contributed to their failure to detect their hydraulic system configuration error.

The Safety Board believes that the FAA should require all principal operations inspectors (POIs) of 14 CFR Part 121 operators using DC-9 and MD-80 airplanes with the "HI, LOW, OFF" hydraulic switch configuration to ensure that operating manuals and training programs include information about the consequences of improper hydraulic system configuration, specifically that the flaps and landing gear will not function normally if the engine-driven hydraulic pumps are not set to "HI."

Cockpit Resource Management (CRM) Training

According to flight data recorder (FDR) data, 34 seconds before touchdown, the airplane was 504 feet AFE and traveling at 216 knots indicated airspeed. This speed was 84 knots faster than the target airspeed of 132 knots established by the flightcrew during completion of the descent checklist. In addition, the speed was 63 knots faster than the reference airspeed of 153 knots for a flaps-up, slats-extended landing at a weight of 86,000 pounds. The COA DC-9 Flight Manual current at the time of the accident

described a stabilized approach as flight on the desired glide path at a steady rate of descent, on the target speed in landing configuration, in trim, and with the proper thrust setting. The manual stated that unstabilized approaches must not be allowed to continue below 500 feet AFE. The approach was clearly unstabilized when the airplane descended through 500 feet; yet, the flightcrew failed to discontinue the approach.

The first officer told Safety Board investigators that his goal after recognizing that the flaps were not extended was to get the captain to initiate a go-around. Thirty seconds before touchdown, the first officer stated "want to take it around?" and the captain replied "no that's alright. * keep your speed up here about uh." When the captain denied the first officer's request to go around and told him to keep his speed up, the first officer did not challenge the captain's statement. He also did not question the captain to determine his reason(s) for continuing the approach. The first officer stated that there was no time for discussion with the captain because the approach was so fast. The first officer's failure to question the captain's decision to continue the approach was inconsistent with the CRM training he had received that emphasized the importance of sharing doubts with other crewmembers and quickly resolving conflicts.

The first officer's failure to assert himself and overtly challenge the captain's decision to continue the approach must be evaluated in the context of the strategy he had developed after an incident in 1994 when he was removed from duty for 60 days and sent to a psychiatrist for evaluation following a captain's complaint. The first officer described the incident as "terribly damaging" to him personally and professionally. He told Safety Board investigators he believed his career would be in jeopardy if another captain complained to management about him. Therefore, after the incident, he adopted a cautious and deferential mode of interaction with captains to prevent a recurrence, even though this style of communication could on occasion conflict with the CRM training he had received.

Although the first officer failed to overtly challenge the captain's decision to continue the approach, he did continue providing information to the captain about the quality and stability of the approach. Five seconds after the captain rejected his go-around request by stating "no you're alright," the first officer said "I can't slow it down here now." The captain again stated "you're alright," and the first officer replied "we're just smokin' in here." The Safety Board concludes that although the first officer was unwilling to overtly challenge the captain's decision to continue the approach, he did attempt to communicate his concern about the excessive speed of the approach to the captain.

Nonetheless, the Safety Board is concerned that a pilot was disinclined to assertively challenge another pilot's decision, despite having completed CRM training advocating that he do so, because he feared reprisal. Therefore, the Safety Board believes that the FAA should require all POIs of 14 CFR Part 121 carriers to ensure that the carriers establish a policy and make it clear to their pilots that there will be no negative repercussions for appropriate questioning in accordance with CRM techniques of another pilot's decision or action. In addition, the Safety Board believes that the FAA should

require all POIs of 14 CFR Part 121 carriers to ensure that CRM programs provide pilots with training in recognizing the need for, and practice in presenting, clear and unambiguous communications of flight-related concerns.

Adequacy of COA and FAA Oversight

In its study of flightcrew-involved major accidents, the Safety Board documented the significance of improperly completed checklists and failure to follow standard operating procedures in accident causation.[3] The COA flight 1943 accident was the third flightcrew-involved accident at COA in 28 months. The frequency of these accidents suggests that the company response and FAA oversight after the previous accidents may have been inadequate.

Findings from an August 1995 National Aviation Safety Inspection Program (NASIP) report appeared to show that COA had corrected deficiencies identified after the previous accidents and FAA inspections. However, only 6 months later, the flightcrew of the accident airplane consistently deviated from standard operating procedures, including failing to properly perform checklists and engaging in nonessential conversation below 10,000 feet. In addition, the day after this accident, a COA B-737 overran the runway on landing at DCA, and again, the Safety Board found evidence of deviations from standard operating procedures, specifically the captain's failure to discontinue an unstabilized approach.

In the weeks following the accident, there was evidence of improper checklist execution and sterile cockpit violations found and later reported by the NASA/University of Texas/FAA-sponsored Aerospace Crew Research Project team. The Safety Board is especially concerned that procedural violations were observed in the weeks after the accident, yet the FAA NASIP inspection 6 months before the accident failed to detect any procedural deviations, and the POI had seen no trends in the area of noncompliance with Federal regulations or company procedures during his tenure as POI (1991 to present). Finally, during this investigation, Safety Board investigators learned that some pilots at COA used operational norms that had been developed on the line and were contrary to standard operating procedures acquired during training. That COA management was aware of and apparently concerned by these norms, is evident from a CRM course attended by Safety Board investigators in which the instructor emphasized the importance of rejecting short-cuts and norms that deviate from standard operating procedures.

Based on the findings of this investigation, the Safety Board concludes that there were deficiencies in COA's oversight of its pilots and the POI's oversight of COA. In addition, the Safety Board concludes that COA was aware of inconsistencies in flightcrew adherence to standard operating procedures within the airline; however, corrective actions taken before the accident had not resolved this problem. Thus, the Safety Board believes the FAA should require COA to audit its internal oversight process and correct

[3] See Safety Study—"A Review of Flightcrew-Involved, Major Accidents of U.S. Air Carriers, 1978 through 1990" (NTSB/SS-94/01).

deficiencies in that oversight process that allow deviations from standard operating procedures and violations of Federal regulations to go uncorrected, and to develop a specific plan to reinforce the importance of adherence to standard operating procedures among pilots. In addition, the Safety Board believes that the FAA should audit its surveillance of COA en route operations to determine if the surveillance is adequate to identify procedural deficiencies in COA's operations.

Checklist Design

In the summer of 1996, COA independently initiated a comprehensive evaluation of checklist philosophy, usage, and format across its fleet. The evaluation is ongoing, and COA has received guidance from experts on human factors in this effort. According to COA management personnel, the company intends to modify its checklists to comply with guidelines for checklist design and usage derived through NASA-sponsored research.[4] These guidelines are designed to help prevent crew omissions, promote redundancy, and prioritize safety-critical information.

The Safety Board is encouraged by the steps that COA has taken to bring its checklists into compliance with contemporary human factors research on checklist design and usage. During its investigation, the Safety Board noted deficiencies in COA checklists that are contrary to these guidelines and should be addressed in the checklist revisions.

The Safety Board has addressed the issue of inadequate checklist procedures by airline pilots several times over the years. The Board issued Safety Recommendation A-94-001,[5] which specifically addressed the design of taxi checklists, to the FAA as a result of the Board's study of flightcrew-related accidents.[6]

In a December 18, 1996, letter the FAA responded to the Safety Board detailing actions taken to address Safety Recommendation A-94-001. The FAA's actions included: (1) mandating CRM training for certificate holders required to comply with 14 CFR Part 121 training requirements, (2) revising Advisory Circular 120-51B "Crew Resource Management Training" to address training in challenging errors involving inadequately completing checklists and to provide clarifying CRM guidance in respect to checklist procedures, (3) issuing Flight Standards Information Bulletin 95-20, which instructs POIs of 14 CFR Part 121 and 135 carriers to reemphasize the need to strictly comply with

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[4] Degani, A. & Weiner, E. Human Factors of Flight-Deck Checklists: The Normal Checklist, NASA Contractor Report 177549, May, 1990.

[5] A-94-001 states the following: "Apply the results of research conducted to date on the design and use of checklists to improve the error-tolerance of air carrier checklist procedures for taxi operations by enhancing flightcrew monitoring/challenging of checklist execution, providing cues for initiating checklists, and considering technological or procedural methods to minimize the omission of any items on a checklist. Provide specific guidance to air carriers for implementing these procedures."

[6] See Safety Study—"A Review of Flightcrew-Involved, Major Accidents of U.S. Air Carriers, 1978 through 1990" (NTSB/SS-94/01).

standard operating procedures and in-flight checklist procedures, and (4) issuing a report in January 1995 entitled "Human Performance Considerations in the Use and Design of Aircraft Checklists," which summarizes contemporary human factors principles affecting the design and use of all aircraft checklists, not only taxi checklists as stated in A-94-001. The report also provides guidance on checklist design.

On October 30, 1996, the report was distributed to all FAA headquarters, regional, and field offices accompanied by a memorandum from the Director of Flight Standards Service (AFS-1) stating the following, in part:

> [this report] is a tool which can be used by operators in the design, development, and use of new aircraft checklists. The report can also be used in the revision of existing checklists, as needed. Several reports, for employees and operators, are included with this memorandum.

Based on the FAA's actions, including the production and distribution of this report, the Safety Board now classifies A-94-001 "Closed—Acceptable Action."

Although the FAA has satisfied the intent of A-94-001, the Board notes that to date, the FAA has not provided a mechanism to ensure that checklists of air carriers comply with the guidance provided in the FAA's recently issued report. The Safety Board concludes that this accident demonstrates the need for all air carriers to bring their checklists that apply to all phases of ground and flight operations into compliance with the contemporary human factors principles of checklist design outlined in the FAA's report. While it appears that the current COA-initiated review of checklists and checklist procedures may accomplish this end at COA, the Safety Board is concerned that other airlines' checklists may not benefit from the guidance set forth above. Therefore, the Safety Board believes that the FAA should require that POIs review the checklists of air carriers operating under 14 CFR Parts 121 and 135 to ensure that they comply with the guidance presented in the FAA report entitled "Human Performance Considerations in the Use and Design of Aircraft Checklists, " and require that any checklists that do not comply with the guidance be revised accordingly.

Survival Factors

After flight 1943 came to a stop on the runway, the "C" flight attendant was unable to completely remove the tailcone access plug door because one of the aft jumpseat shoulder harness straps was buckled to the lap belt, which tied the plug door to the aft cabin bulkhead. Fortunately, the lack of availability of the tailcone exit did not preclude a timely and successful evacuation.

When Safety Board investigators examined the DC-9 plug door training device at COA's Houston flight attendant training facility, they found that seat belts and shoulder harnesses were not installed in the trainer. Therefore, it was not possible for flight attendants to practice attempting to remove the plug door with the shoulder harness straps

buckled to the seat belt and gain hands-on experience with the problem this creates. In addition, the COA Inflight Manual current at the time of the accident did not mention the need to ensure that the jumpseat shoulder harness straps are unbuckled from the lap belts before attempting to remove the plug door. The Safety Board concludes that COA flight attendants received inadequate information and training on the operation of the DC-9 tailcone access plug door. As a result of the Safety Board's accident investigation, COA has equipped its DC-9 plug door trainer in Houston (as well as those at its flight attendant training facilities in Newark, New Jersey, and Cleveland, Ohio) with shoulder harnesses and seat belts. In addition, COA revised the Inflight Manual to include information on the consequences of attempting to remove the plug door without first ensuring that the shoulder harness straps are released.

HBAT 96-02 provides guidelines for approval of tailcone training devices by FAA inspectors and states, "if a shoulder harness is attached to the door in the aircraft that might interfere with the opening of the door, one should be similarly attached to the corresponding door in the training device." However, because of the omission of a requirement in HBAT 96-02 that seat belts be installed in plug door trainers, the Safety Board believes that the FAA should amend HBAT 96-02 to include a requirement that if any portion of a restraint system is attached to the tailcone access plug door in the aircraft that might interfere with the opening of the door, the plug door training device must be equipped with the entire restraint system.

Therefore, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Require all DC-9 and MD-80 operators with the "HI, LOW, OFF" hydraulic switch configuration to revise their checklists to emphasize the importance of the "Hydraulics" item by placing it as the first item on the in-range checklist (or equivalent), and requiring that both pilots verbally verify hydraulic pump switch settings and system pressures. (A-97-3)
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> Require all principal operations inspectors of 14 CFR Part 121 operators using DC-9 and MD-80 airplanes with the "HI, LOW, OFF" hydraulic switch configuration to ensure that operating manuals and training programs include information about the consequences of improper hydraulic system configuration, specifically that the flaps and landing gear will not function normally if the engine-driven hydraulic pumps are not set to "HI." (A-97-4)
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> Require all principal operations inspectors of 14 CFR Part 121 carriers to ensure that the carriers establish a policy and make it clear to their pilots that there will be no negative repercussions for appropriate questioning in accordance with crew resource management techniques of another pilot's decision or action. (A-97-5)

Require all principal operations inspectors of 14 CFR Part 121 carriers to ensure that crew resource management programs provide pilots with training in recognizing the need for, and practice in presenting, clear and unambiguous communications of flight-related concerns. (A-97-6)

Require Continental Airlines to audit its internal oversight process and correct deficiencies in that oversight process that allow deviations from standard operating procedures and violations of Federal regulations to go uncorrected, and to develop a specific plan to reinforce the importance of adherence to standard operating procedures among pilots. (A-97-7)

Audit its surveillance of Continental Airlines (COA) en route operations to determine if the surveillance is adequate to identify procedural deficiencies in COA's operations. (A-97-8)

Require that principal operations inspectors review the checklists of air carriers operating under 14 CFR Parts 121 and 135 to ensure that they comply with the guidance presented in the Federal Aviation Administration report entitled "Human Performance Considerations in the Use and Design of Aircraft Checklists, " and require that any checklists that do not comply with the guidance be revised accordingly. (A-97-9)

Amend Flight Standards Handbook Bulletin 96-02, "Guidelines for Crewmember Training on Aircraft Tailcones and Approval of Tailcone Training Devices," to include a requirement that if any portion of a restraint system is attached to the tailcone access plug door in the aircraft that might interfere with the opening of the door, the plug door training device must be equipped with the entire restraint system. (A-97-10)

Chairman HALL, Vice Chairman FRANCIS, and Members HAMMERSCHMIDT, GOGLIA, and BLACK concurred in these recommendations.

By: Jim Hall
Chairman