Log 1755

NATIONAL TRANSPORTATION SAFETY BOARD
WASHINGTON, D.C.

ISSUED: November 16, 1984

Forwarded to:

Honorable Donald D. Engen
Administrator
Federal Aviation Administration
Washington D.C. 20591

SAFETY RECOMMENDATION(S)
A-84-123 and -124

On February 28, 1984, Scandinavian Airlines System (SAS) Flight 901, a McDonnell Douglas DC-10-30 of Norwegian Registry, was a regularly scheduled international passenger flight from Stockholm, Sweden, to John F. Kennedy International Airport (JFK), New York, with an en route stop at Oslo, Norway. Following a category II instrument landing system (ILS) approach to runway 4 Right at JFK, the airplane touched down long and fast after which it rolled off the end of the runway and came to rest with its nose partially submerged in a tidal waterway about 600 feet beyond the departure end of the runway. All of the 163 passengers and 14 crewmembers evacuated the airplane safely, but with some injuries. 1/

The Safety Board determined that the probable cause of this accident was the flightcrew's (a) disregard for prescribed procedures for monitoring and controlling of airspeed during the final stages of the approach, (b) decision to continue the landing rather than to execute a missed approach, and (c) overreliance on the autothrottle speed control system which had a history of recent malfunctions.

The Safety Board's investigation disclosed that the landing approach was conducted in weather characterized by low ceilings, low visibility, and light drizzle and fog. The examination of the data from the airplane's digital flight data recorder and the airplane's integrated data system recorder indicated that the approach was normal as the airplane descended to about 800 feet above ground level. Although the groundspeed showed that the airplane was experiencing a tailwind component which decreased gradually from 30 knots at the outer marker to zero at ground level, the indicated airspeed was stable and the airplane was following the ILS glideslope.

1/ For more information read, Aircraft Accident Report: "Scandinavian Airlines System, DC-10-30, John F. Kennedy International Airport, Jamaica, New York, February 28, 1984." (NTSB-AAR-84/15.)

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After descending through 800 feet, however, the indicated airspeed increased to a point that the airplane passed over the runway threshold about the proper crossing height, but about 50 knots faster than the prescribed approach reference speed. Thereafter, the airplane floated, touching down on the runway about 4,700 feet beyond the threshold and about 36 knots faster than the normal touchdown speed.

The flightcrew's recollections following the accident indicate that neither the captain nor his copilot was totally aware of the airplane's increasing airspeed during the final approach. The investigation disclosed that the flightcrew was using the airplane's autothrottle speed control system during the approach. Based in part upon a number of previous reported discrepancies in the autothrottle speed control system, the Safety Board concluded that an intermittent fault in the system caused it to malfunction on the approach to accelerate the airplane beyond the selected approach airspeed. The Safety Board's analysis was, therefore, directed toward reasons why the flightcrew apparently failed to note the increased airspeed and thus allowed the autothrottle system to control the airplane to an airspeed nearly 40 knots higher than the selected value. The Safety Board is concerned that an experienced, well-trained flightcrew whose previous record of performance was unblemished had a lapse in which they neglected the basic airmanship function of controlling airspeed on approach. Two factors which probably affected the crew's performance were (1) its habitual reliance on the proper functioning of the airplane's automatic system, and (2) a degradation of crew coordination and nonadherence to related procedures when the first officer is flying the airplane.

Reliance on the Automated System

Since the introduction of sophisticated automation that accompanied the wide-body generation of aircraft, there has been much controversy and concern over the resulting relationship between man and machine. As more computers have been added to the aircraft and control of tasks has been transferred to autopilot and autothrottle systems, the pilot's role in the aircraft operation has changed dramatically. His workload as far as physically handling the aircraft was reduced, and in some phases of flight, totally eliminated. According to one researcher in this field: "As computers are added to the cockpit, the pilot's job is changing from one of manually flying the aircraft to one of supervising computers which are doing navigation, guidance and energy management calculations as well as automatically flying the aircraft." 2/

However, with increased automation, overall pilot workload was not necessarily reduced. In most cases, it merely has shifted from controlling tasks to monitoring tasks. Because increasingly more systems have been automated, a proliferation of components has resulted and the pilot "has many more indicators of component status to monitor." 3/ There is convincing evidence, from both research and accident statistics, that people make poor monitors. The following is just a small sampling:

2/ Palmer, E., Models for Interrupted Monitoring of a Stochastic Process. NASA TM-78, 453, 1977, p.1.
3/ Wickens, C.D., Engineering Psychology and Human Performance. Columbus, Ohio; Charles E. Merrill Publishing Company, 1984, p. 490.

1) Kessel and Wickens did a laboratory study to compare failure detection performance between manual and automated systems. In the manual mode, participants were actively controlling a dynamic system and in the automatic mode they were monitoring an autopilot that controlled the system. It was found that "detection performance was faster and more accurate in the manual as opposed to the autopilot mode." 4/ These results were attributed to the fact that in the manual mode, the participants remained in the "control loop" and they benefited from additional proprioceptive cues derived from "hands-on" interaction with the system. These findings were in agreement with a research study by L.R. Young. 5/

2) In the 1972 Eastern Airlines L-1011 crash into the Everglades, 6/ the crew was distracted by a malfunctioning landing gear light and failed to monitor the autopilot which was flying the aircraft.

   The autopilot was accidentally disengaged and the aircraft gradually descended from the holding pattern. Without an autopilot, one crewmember would have been forced to fly the aircraft and the disaster could have been avoided.

3) In 1979, the crew of an Aeromexico DC-10 stalled the aircraft on climbout over Luxembourg. In this incident, the crew either intentionally or inadvertently programmed the autopilot for the vertical speed mode rather than the procedurally directed airspeed or mach command mode. The aircraft maintained the programmed climb rate throughout the climbout, but at the sacrifice of airspeed. As thrust available decreased with altitude, the engines could no longer sustain flying airspeed for that climb rate and the aircraft stalled, losing approximately 11,000 feet of altitude before recovery. The Safety Board concluded that, "The flight crew was distracted or inattentive to the pitch attitude and airspeed changes as the aircraft approached the stall." The probable cause of the incident was listed as "the failure of the flightcrew to follow standard climb procedures and to adequately monitor the aircraft's flight instruments." 7/

4) Another incident, almost identical to that which occurred on the Aeromexico flight, is cited in a NASA Aviation Safety Reporting System (ASRS) report as follows:

4/ Kessel, C. and Wickens, C.D., The Internal Model: A Study of the Relative Contribution of Proprioception and Visual Information to Failure Detection in Dynamic Systems; NASA CP-2060, 1978, pp. 85-86.
5/ Young, L.R., On Adaptive Manual Control; IEEE Transactions on Man-Machine Systems, Vol. MMS-10, 1969, pp. 292-331.
6/ Aircraft Accident Report: "Eastern Airlines L-1011, Miami, Florida, December 29, 1972." (NTSB -AAR- 73-14.)
7/ Aircraft Incident Report: "Aeromexico DC-10-3-, XA-DUH, Over Luxembourg, Europe, November 11, 1979." (NTSB- AAR-80-10.)

The aircraft was climbing to FL 410 with the right autopilot and autothrottles engaged and controlling the aircraft. At approximately FL 350 the airspeed was observed to be below 180 knots and decaying. The autopilot was disengaged and the nose attitude was lowered. At this point the stickshaker activated and a slight buffet was felt. Application of full power and a decrease in pitch attitude returned the airspeed to normal. Remainder of the flight was uneventful.

During the climb portion of the flight, I believed the autopilot was in the Flight Level Change Mode (max climb power and climbing while maintaining a selected airspeed/mach). Looking back I now feel the autopilot must have been in the Vertical Speed mode, and not Flight Level Change.

If this were the case with 2,500/3,000 feet per minute up selected, then the airspeed would be near normal to about FL 300 at which point the airspeed would bleed off as the autopilot maintained the vertical speed.

Prevention of this incident: the pilot must at all times be absolutely sure what mode the autopilot is operating in. A continuous cross- check of the primary flight instruments would have indicated decreasing airspeed before it became a serious problem. 8/

In 1976, a technical paper entitled "The Automatic Complacency" was presented by an SAS captain to his colleagues. The summary of the paper follows:

This paper discusses the man-machine problem that faces the pilot in his role as a programmer and supervisor in an environment that provides automatic systems to do the work but where the redundancy concept requires the man to be in a "continuous loop" function.

The paper recognizes the problem as "normal," human-engineering wise but a problem that has to be solved by giving the pilot strong incentives to interface himself with the functions of the automatics and to subordinate himself to the requirements of tedious monitoring routines and stringent flight deck procedures which he may feel as superfluous in view of the normally excellent performance of the automatic systems.

Researchers claim that the reliability of the automation equipment may account for the reduced vigilance of pilots using automated systems. Very unreliable equipment would lead pilots to expect malfunctions and to be proficient at handling them. A system that never failed would not pose a problem but one with an intermediate level of failure may prove "quite insidious since it will induce an impression of high reliability, and the operator may not be able to handle the failure when it occurs." 9/

8/ Lauber,J.K., Cockpit Resource Management in New Technology Aircraft, presented at International Aeronautical Symposium sponsored by Japanese Air Line Pilots' Association, August 16-18, 1982, p.11.
9/ Wiener, E.L., and Curry, R.E., Flight-Deck Automation: Promises and Problems, NASA TM-81206, p. 10.

The captain of SAS Flight 901 knew that the authothrottle speed control system had malfunctioned on the first leg of the flight. However, 10 hours had elapsed since the malfunction and the captain had over 5 years experience with successful autothrottle operation. Consequently, the Safety Board believes that the captain's failure, and the copilot's failure to monitor the approach airspeed can be attributed, in part, to behavioral tendencies such as those described in the aforementioned research. The pilots' overreliance on the autothrottle system was, therefore, considered to be a major factor in the accident cause.

In fact, dealing with an excursion from a stabilized condition may be unduly delayed when a system anomaly is detected, because of the "warm up" period required for a pilot to transition from system monitor to system controller. Time is needed to "ascertain the current status of the airplane and assess the situation," 10/ before the pilot can reenter the control loop and take corrective action.

In this accident about 20 seconds before touchdown, the copilot switched the autopilot from the command to the control wheel steering mode, a mode in which he manually controls the airplane's attitude. This action placed the copilot into the control loop but apparently did not prompt him to recognize or correct the excessive airspeed. The Safety Board believes that the SAS copilot's performance illustrates the difficulties in the transition from a monitoring to a control function as described by the researchers.

Researchers have also concluded that "prolonged use of a system in the automatic mode may lead to a deterioration of manual skills and a loss of proficiency, which may degrade performance on a manual system." 11/ Thus, even after detection of anomalous performance of an automatic system, the pilot's ability to control precisely an airplane after he reenters the control loop is degraded. Another researcher noticed that "many crewmembers have discovered this [proficiency loss] on their own and regularly turn off the autopilot, in order to retain their manual flying skills." 12/ During its investigation of this accident and associated interviews with crewmembers, the Safety Board learned that SAS and other airlines, as well as airplane manufacturers, teach and encourage the use of automated systems such as the autothrottle. Initially, flightcrews were reluctant to use them, but now they are reluctant to fly without them.

While the Safety Board believes that on balance automation has greatly improved safety and has reduced pilot workload and fatigue, there is an ever-increasing need to reemphasize to crews the need to effectively monitor critical flight instruments and systems. This requirement may be satisfied, in part, by introduction of procedures specifically designed to enhance crew awareness of excursions from programmed performance. In addition, the flightcrew training program must be focused toward measures to ameliorate the adverse effects of automation on crew proficiency and performance which are apparent from recent research and which are illustrated by this and several past accidents.

Crew Coordination— Procedures and Training

A comparison of the cockpit voice recorder transcript with SAS airspeed and altitude callout procedures disclosed that the crew omitted several required calls during the ILS approach to JFK. Altitude callouts were not made for "Glide Path Coming" and "Glide Path Capture."

10/ Boehm-Davis, D.A., Curry, R.E., Wiener, E.L. and Harrison, R.L., Human Factors of Flight-Deck Automation - NASA/Industry Workshop, NASA TM-81260, January, 1981, p. 6.
11/ Ibid.
12/ Wiener, op. cit., p. 9.

Required airspeed callouts were neglected even more than altitude calls, and this may have contributed to the crew's lack of airspeed awareness. The purpose of airspeed and altitude callouts is to provide checks and balances between flightcrew members. Verbalizing selected performance parameters not only reinforces each crewmember's perception of aircraft performance, it also enables pilots to better assess each other's situational awareness.

In another accident investigated by the Safety Board, the adverse effect of neglecting required callouts on crew coordination and performance also was illustrated. On July 9, 1978, the captain of an Allegheny Airlines BAC 1-11 flew an uncoupled ILS approach 61 knots above reference speed and landed about half-way down runway 28 at Monroe Airport, New York. The aircraft came to rest over 700 feet past the departure end of the runway. In its report of the accident, 13/ the Safety Board stated:

> The National Transportation Safety Board determines that the probable cause of the accident was the captain's complete lack of awareness of airspeed, vertical speed, and aircraft performance throughout an ILS approach and landing in visual meteorological conditions which resulted in his landing the aircraft at an excessively high speed and with insufficient runway remaining for stopping the aircraft, but with sufficient aircraft performance capability to reject the landing well after touchdown. Contributing to the accident was the first officer's failure to provide required callouts which might have alerted the captain to the airspeed and sink rate deviations. The Safety Board was unable to determine the reason for the captain's lack of awareness or the first officer's failure to provide required callouts."

The speed callout procedures set forth in the SAS Flight Operations Manual, requiring only a callout of "speed high" or "speed low" when the final approach and threshold speeds differ by more than 5 knots from the proper speed, may not be sufficient to alert a crewmember to a dangerously high or low speed condition. The captain of SAS Flight 901 called "high" at about 150 feet radio height on the approach. At this point, the aircraft speed was about 208 knots indicated airspeed (KIAS) rather than the targeted 168 KIAS. While the Safety Board believes that the current "speed high" callout should trigger increased monitoring and assessment by the flightcrew of the indicated versus targeted airspeed, it also believes that calling out the actual speed values, i.e., deviations from the target airspeed, would serve as a more positive warning to initiate corrective measures and/or abandon the approach, whichever is applicable.

We believe that, if the captain had called out that the airspeed was 40 knots above reference speed, or "plus 40" rather than "speed high," during the final stages of the approach, the accident involving Flight 901 may possibly have been averted.

In summary, the Safety Board believes that the recent history of accidents and incidents involving automation dictate the need for remedial action. Further, the extensive research findings regarding the effects of automation on flightcrew proficiency and performance reinforce the need for remedial action. The Safety Board believes that the lessons learned from accident/incident investigations and from the research should be heeded by enhancing pilot procedures and pilot training programs. In addition, the Safety Board believes that air carrier airspeed callout procedures should be revised to enhance crew coordination.

13/ Aircraft Accident Report: "Allegheny Airlines, Inc., BAC 1-11, N1550, Rochester, New York, July 9, 1978." (NTSB-AAR-79-2.)

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

> Apply the findings of behavioral research programs and accident/incident investigations regarding degradation of pilot performance as a result of automation to modify pilot training programs and flight procedures so as to take full advantage of the safety benefits of automation technology. (Class II, Priority Action) (A-84-123)
>
> Direct air carrier principal operations inspectors to review the airspeed callout procedures of assigned air carriers and, where necessary, to require that these procedures specify the actual speed deviations (in appropriate increments, i.e., +10, +20, -10, -20, etc.) from computed reference speeds. (Class II, Priority Action) (A-84-124)

BURNETT, Chairman, GOLDMAN, Vice Chairman, and BURSLEY, Member, concurred in these recommendations.

Jim Burnett

By: Jim Burnett
Chairman