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# NATIONAL TRANSPORTATION SAFETY BOARD
## WASHINGTON, D.C.

ISSUED: April 15, 1985

Forwarded to:

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

SAFETY RECOMMENDATION(S)
A-85-26 and -27

On May 31, 1984, at 1334 mountain daylight time, United Airlines Flight 663, a Boeing 727-222, N7647U, departed Denver, Colorado, for Las Vegas, Nevada, with 98 passengers and 7 crewmembers onboard. At that time, wind shear was being reported at Denver's Stapleton International Airport with the centerfield wind from 280° at 22 knots, gusting to 34 knots. During the takeoff from runway 35L, the aircraft lost knots of airspeed at rotation and used almost the entire length of the runway to reach takeoff and climb speed. However, almost immediately after it began its climb, the aircraft struck the localizer antenna located 1,074 feet beyond the end of the runway at a height of 15 feet above the ground. No one was hurt as a result, but the aircraft fuselage was damaged substantially. The aircraft climbed to 10,000 feet altitude before the crew realized that the cabin could not be pressurized. The crew returned to Denver, landing the aircraft without incident.

On June 13, 1984, at 1656 eastern daylight time, USAir Flight 183, from Hartford, Connecticut, a DC9-31, N964VJ, with 50 adult passengers, 1 infant passenger, and 5 crewmembers crashed at Detroit Metropolitan Airport while attempting a go-around following an instrument landing system (ILS) approach to runway 21R. Although no one was killed in the crash, five persons were injured, and the aircraft was damaged substantially. At the time of the accident, there was heavy rain, hail, and low-level wind shear reported at the airport.

In both these accidents, transport category aircraft encountered wind shear after air traffic controllers transmitted wind shear reports in conditions in which there was a high probability of a wind shear encounter. In Denver, virga 1/ was present and the temperature and dewpoint spread was more than 40° F; both of these factors suggest a

1/ A situation in which precipitation and hail fall beneath clouds and evaporate before reaching the ground, producing a streamer-like effect. It generally occurs at higher altitudes and is often accompanied by turbulence.



AAR-85-1

strong possibility for wind shear. In Detroit, a thunderstorm was in progress in the immediate vicinity of the airport, also a factor indicating the likely presence of a microburst type of wind shear. 2/

Both United and USAir regularly inform their pilots through written material and films of the dangers inherent in wind shear encounters. The consequences of these hazards were illustrated dramatically by the crash of Pan American World Airways Flight 759 on July 9, 1982, at Kenner, Louisiana. 3/ In that case, wind shear was present and had been reported by the local controller.

The flightcrews of the aircraft reacted differently to the respective hazardous situation they each faced. The second officer on United Flight 663, according to the crewmembers' statements, strongly asserted, "Captain, you've lost 20 knots of airspeed." The captain immediately advanced the throttles to their mechanical limits and adjusted the aircraft pitch attitude to reduce to a minimum any decrease in the initial climb rate. These timely actions were critical in preventing a more severe accident and a potential catastrophe.

The flightcrew of USAir Flight 183 was unsure of the winds, which exceeded the carrier's DC9 crosswind landing limitations, and failed to ask for clarification on the nature of the winds. According to the cockpit voice recorder transcript, there was no discussion initiated by either crewmember on the need for more current wind or visibility information or on the possibility of discontinuing the approach and initiating a go-around. The aircraft entered a thunderstorm cell located on the approach path to runway 21R, where it encountered substantial turbulence, heavy rain, and hail. Once outside the cell, it encountered a strong tailwind and contacted the runway with the landing gear only partially extended.

Investigations into the two accidents have focused on the role of the Low Level Wind Shear Alert System (LLWAS) in supplying pilots with meaningful wind shear-related information. In addition, the types of training that both United and USAir provided their pilots in cockpit crew coordination and wind shear recognition and response were examined for their roles in the crew performance in the two accidents.

In a wind shear environment, immediate access by flight crewmembers to wind data is particularly critical since wind shear is such a dynamic phenomenon where conditions can change rapidly and dramatically. The Safety Board recognizes that despite the variety of information available to pilots on the presence of wind shear, none offers a precise measurement of the hazards that pilots can expect to encounter. As a result, pilots in command must make the most prudent decision possible, using all available information, on the advisability of conducting a flight into a wind shear environment. There are no absolute standards available to crewmembers, such as there are for prevailing visibility for example, that will categorically permit or prohibit a takeoff or a landing.

One source of information available to pilots on wind shear conditions is the LLWAS, which measures wind directions and velocities at locations around the

2/ Wind shear is a change in wind direction and speed in a very short distance in the atmosphere. A microburst is a downdraft that spreads out horizontally upon reaching the surface, thereby producing a diverging radial flow of air in all directions.

3/ Aircraft Accident Report--"Pan American World Airways, Inc., Clipper 759, Boeing 727-235, N74737, New Orleans International Airport, Kenner, Louisiana, July 9, 1982" (NTSB/AAR-83/02).

airport. If velocity vector differences exceed 15 knots, an alarm is sounded and the controller informs pilots of the winds in the appropriate locations. The Safety Board recognizes that despite the usefulness of LLWAS alerts, LLWAS is limited by present technology. For example, it cannot measure winds in the approach and departure paths above ground level, or even ground level winds except in the immediate vicinity of sensors.

In attempting to understand why experienced crewmembers would continue to operate in the face of LLWAS wind shear reports, the Safety Board examined the nature of the reports themselves. LLWAS reports are transmitted to pilots immediately before or during pilots' heaviest workload periods, generally, before taking off or landing. Prior to takeoff, crewmembers can more effectively use the information on wind shear in making their decision on whether to take off. According to their statements, the crew of United Flight 663 did this in planning their takeoff flap and engine thrust settings and speeds. However, when LLWAS information is given to crews shortly before they land, they have limited time available to interpret and act on the data. Moreover, wind shear generally occurs in adverse weather conditions when crew workload is already high.

This situation is exacerbated by the volume of the data collected by the LLWAS. There are generally five LLWAS wind sensors at airports in addition to the centerfield wind sensor. Thus, controllers can provide the pilots with 12 or more pieces of information consisting of wind direction in magnetic heading and velocity in knots, from the centerfield sensor and each of the five peripheral sensors. A typical report could be: Centerfield winds three zero zero at two five, peak gusts, four zero, north boundary winds three two zero degrees at one eight, east boundary winds three one zero degrees at five. This resembles the type of wind shear advisory that was given to the United crew and to the USAir crew. In both cases, the speech rate of the controller was rapid.

Studies as far back as 1956 4/ have shown consistently that the human short-term memory limitation averages about seven pieces of information, ranging from five to nine. Thus, it is virtually impossible for someone who is given 12 pieces of numerical data to remember the data for more than a few seconds, much less assimilate or process it for decisionmaking. Once they are given the LLWAS information, pilots have to process it; that is, they have to understand the implications of the varying winds on the safety of operating their aircraft along planned takeoff or landing paths. However, several factors effectively preclude pilots from doing this. For the most part, LLWAS sensors have been placed at the busiest airports, so that controllers rarely have sufficient time, while carrying out their primary duties of controlling aircraft, to report the winds at a rate that is slow enough for pilots to record the information and then analyze it. Secondly, wind shear conditions are rarely stable and can and often will change after the controller reports them. Finally, wind shear reports are not always transmitted at the most opportune times in flight to enable pilots to analyze the information while occupied with their primary operational duties.

As a result, pilots often ignore LLWAS reports or wait until they receive corroborating evidence of wind shear conditions, such as pilot reports (PIREPS). Without corroborating information, pilots often will not recognize the hazards present in the conditions described by the LLWAS broadcast. The captain of United Flight 663 stated that a PIREP of a 20-knot airspeed loss by the pilot of a DHC-7 which he

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4/ Miller, G.A. The Magical Number Seven Plus or Minus Two: Some Limits on Our Capacity for Processing Information: Psychological Review, 1956, 63, 81-97.

interpreted incorrectly helped him decide on how to conduct the planned takeoff. He stated that a similar PIREP by a pilot of a transport category turbojet, which has less performance capability in wind shear than a DHC-7 turbo prop airplane, would have given him the information he needed to decide whether or not he could safely proceed with the takeoff. When the crew did not receive a PIREP by the pilot of the turbojet airplane, which took off just before Flight 663, the captain assumed that the takeoff could be safely carried out even though LLWAS data were being broadcast. Similarly, the crew of USAir Flight 183 heard the LLWAS data as they were about to begin their approach in adverse weather. However, their high workload at that time made it almost impossible for them to make effective use of the data.

The Safety Board believes that to increase the utility of LLWAS, the broadcast data should be modified and presented in a manner that is consistent with the limitations of human short-term memory and information processing. Rather than presenting 12 or more numbers at a rapid rate to crewmembers, who then must interpret the wind data for their potential effects on the safety of flight, the Safety Board believes that current computer technology could interpret the data for the crewmembers. This would permit controllers to inform pilots of both the presence of shears and more importantly, their expected relative severity in a manner which is more meaningful to the flightcrews.

The Safety Board addressed this issue in 1983 when it recommended, as a result of the Kenner, Louisiana, accident, that the Federal Aviation Administration (FAA):

> Make the necessary changes to display Low Level Wind Shear Alert System wind output data as longitudinal and lateral components to the runway centerline. (A-83-20)

The FAA responded that it is awaiting the results of a study which, "will result in recommendations for the criteria, basis, content, communication, and display of low level wind information and warning to pilots and air traffic control personnel." As a result, Safety Recommendation A-83-20 is classified, "Open—Acceptable Action." The accidents in Denver and Detroit illustrate the need for accurate, current information for pilots to assist them to make the necessary decisions on aircraft operations in a timely manner. For this reason, the Safety Board reiterates Recommendation A-83-20 and urges the FAA to expedite completion of its study to improve the quality of LLWAS data that are transmitted to pilots and prompt implementation of new procedures.

Both flightcrews received training that met or exceeded Federal Aviation Regulations, but they reacted and performed differently in the accident sequences. The Safety Board realizes that any number of variables can affect pilot behavior and performance. For example, the second officer on United Flight 663 is a management pilot who is a B-727-rated captain and check airman, as well as a rated flight engineer. His role with the company could account for both his assertiveness in the cockpit and the captain's immediate and positive response to his call-out.

Another factor that could account for the difference in response is the difference in cockpit resource management training that the two carriers offer their crews. Cockpit resource management 5/ refers to the use of all flightcrew members to

5/ G. F. Cooper, M. D. White, and J. D. Lauber, eds., Resource Management on the Flight Deck (Moffett Field, California: NASA Ames Research Center, 1980).

enhance pilot decisionmaking, communication, crew interaction, and crew integration. USAir currently offers captains who have been upgraded to that position recently a 2-day classroom-type session in human relations. Other crewmembers do not receive this type of training. United requires all crewmembers to receive formal cockpit resource management training, both initial and recurrent, involving classroom as well as simulator sessions. It should be noted, however, that cockpit resource management training is not required under Federal Aviation Regulations. By offering such progams, both carriers exceeded the requirements of these regulations. In their training of pilot performance, both meet or exceed applicable FAA requirements. They differ, however, in the scope and approach of their cockpit resource management training programs.

The Safety Board believes that United's cockpit resource management training may have played a positive role in preventing a more serious accident from occurring in Denver and that it is an endeavor that should be encouraged. The Board previously has recognized the benefits of this training when it recommended in 1979, as the result of several accident investigations, in which the breakdown in cockpit resource management was identified as a contributing factor, that the FAA:

> Urge . . . operators to ensure that their flightcrews are indoctrinated in principles of flight deck resource management, with particular emphasis on the merits of participative management for captains and assertiveness training for other cockpit crewmembers. (A-79-47)

The FAA, in response, issued an operations bulletin to its air carrier operations inspectors instructing them to urge that their assigned carriers implement such training programs. As a result, the Safety Board classified Safety Recommendation A-79-47 as "Closed--Acceptable Action." However, few carriers have instituted cockpit resource management training in which all flightcrew members participate. The Board believes that the need still exists for all flightcrew members to be trained in cockpit resource management. However, the Board believes also that more research needs to be carried out to answer critical questions regarding the effectiveness of cockpit resource management training programs before such training is made mandatory. Until an effective training methodology can be demonstrated, the Board urges the FAA, air carriers, and research centers to continue to work together to develop and demonstrate an effective training program to enhance cockpit resource management for all flightcrew members.

Airlines differ in the type of simulator-based wind shear training they offer flight crewmembers as did United and USAir. In January 1983, the captain of United Flight 663 had been presented, in the simulator, a wind shear on approach to landing. In January of the following year, he was presented, in the simulator, a wind shear on takeoff. In both instances, the wind shears were modeled on actual wind shear-related aircraft accidents. The second officer had been actively involved in United's efforts, shortly before the accident, to upgrade the company's wind shear simulation. By contrast, according to testimony, the captain of USAir Flight 183 had last been presented a simulator wind shear scenario at least 2 years before the accident, and the first officer had never been presented one.

Current regulations do not require operators to present their flightcrews wind shear scenarios or to maintain records of when, if ever, their pilots were given simulated wind shear encounters during their training programs. The efficacy of such scenarios remains unclear due to a variety of factors, not the least of which is that wind shear is a phenomenon whose nature is still being studied. As a result, it is difficult for operators and manufacturers to establish standard wind shear classroom and simulator training procedures. Effective training must consider a host of dynamic variables including wind direction and velocity, temperature, aircraft weight, and amount of precipitation. In addition, some persons contend that simulator training in wind shear scenarios can lead to flightcrew members believing, incorrectly, that wind shears always can be safely traversed.

At the same time, there are many advantages to simulator wind shear training. Periodic exposure to a simulated wind shear should help to maintain crewmember alertness in recognizing the presence of shears as well as their skill in safely flying through shears. Further, repeated practice in shear encounters can serve to alert crews to the potential hazards that exist in wind shears, hazards which they may not appreciate fully through instructional media other than flight simulators.

Investigations into previous wind shear-related accidents have demonstrated that some of the flightcrews might have traversed the wind shear safely had they used different procedures. 6/ As a result of the Kenner, Louisiana, accident the Safety Board recommended in 1983 that the FAA:

> Recommend to air carriers that they modify pilot training on simulators capable of reproducing wind shear models so as to include microburst penetration demonstrations during takeoff, approach and other critical phases of flight. (A-83-25)

The FAA responded that, as with Safety Recommendation A-83-20, it is awaiting the results of a study on wind shear before it can take specific action in response to the recommendation. Safety Recommendation A-83-25 has been classified as "Open—Acceptable Action."

The Safety Board believes that these accidents point to the need for the FAA, the air carriers, manufacturers, and research organizations to work together to develop a common wind shear training program that would illustrate both wind shear avoidance and encounter procedures during both the takeoff and landing phases of flight. Air carriers, manufacturers, and the FAA could then adopt a common wind shear avoidance and encounter model to be used in air carrier and turbojet pilot flight training.

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

> In cooperation with air carriers and manufacturers, develop a common wind shear training program, and require air carriers to modify airline training syllabi to effect such training. (Class II, Priority Action) (A-85-26)

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6/ Aircraft Accident Report—"Allegheny Airlines, Inc., Douglas DC-9, N994VJ, Philadelphia, Pennsylvania, June 23, 1976" (NTSB-AAR-78-2).

Conduct research to determine the most effective means to train all flightcrew members in cockpit resource management, and require air carriers to apply the findings of the research to pilot training programs. (Class II, Priority Action) (A-85-27)

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

By: Jim Burnett
Chairman