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National Transportation Safety Board

Washington, D.C. 20594

Safety Recommendation

Date: November 15, 1993

In reply refer to: A-93-136 through -141

Mr. David R. Hinson
Administrator
Federal Aviation Administration
Washington, D.C. 20591

On March 31, 1993, the No. 2 engine and engine pylon separated from Japan Airlines, Inc. flight 46E, a Boeing 747-121, that had been wet-leased from Evergreen International Airlines, Inc., shortly after departure from Anchorage International Airport, Anchorage, Alaska. The accident occurred about 1234 Alaska standard time. The flight was a scheduled cargo flight from Anchorage to Chicago-O'Hare International Airport, Chicago, Illinois. On board the airplane were the flightcrew, consisting of the captain, the first officer, and the second officer, and two nonrevenue company employees. The airplane was substantially damaged during the separation of the engine. No one on board the airplane or on the ground was injured.[1]

Flight 46E departed Anchorage about 1224 local time. The flight release/weather package provided to the pilots by Evergreen operations contained a forecast for severe turbulence and indicated that severe turbulence was reported by other large airplanes. As flight 46E taxied onto the runway to await its takeoff clearance, the local controller informed the flightcrew that the pilot of another Evergreen B-747 reported severe turbulence at 2,500 feet while climbing out from runway 6R.

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[1]For more detailed information, read *Aircraft Accident Report*--"Japan Airlines, Inc., Flight 46E, Boeing 747-121, N473EV, In-flight Engine Separation, Anchorage, Alaska, March 31, 1993" (NTSB/AAR-93/06)

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After takeoff, at an altitude of about 2,000 feet, the airplane experienced an uncommanded left bank of approximately 50 degrees. While the desired air speed was 183 knots, the air speed fluctuated about 75 knots from a high of 245 knots to a low of 170 knots. Shortly thereafter, the flightcrew reported a "huge" yaw, the No. 2 throttle slammed to its aft stop, the No. 2 reverser indication showed thrust reverser deployment, and the No. 2 engine electrical bus failed. Several witnesses on the ground reported that the airplane experienced several severe pitch and roll oscillations before the engine separated.

Shortly after the engine separated from the airplane, the flightcrew declared an emergency, and the captain initiated a large radius turn to the left to return and land on runway 6R. The No. 1 engine was maintained at emergency/maximum power. While on the downwind portion of the landing pattern, bank angles momentarily exceeded 40 degrees, alternating with wings level. About 1245, flight 46E advised the tower that they were on the runway.

The National Transportation Safety Board determined that the probable cause of this accident was the lateral separation of the No. 2 engine pylon due to an encounter with severe or possibly extreme turbulence that resulted in dynamic multi-axis lateral loadings that exceeded the ultimate lateral load-carrying capability of the pylon, which was already reduced by the presence of the fatigue crack near the forward end of the pylon's forward firewall web.

The investigation found that the flightcrew was properly certificated and qualified in accordance with applicable Federal Aviation Regulations (FARs) and company requirements. The pilots were in good general health and had proper Federal Aviation Administration (FAA) medical certificates at the time of the accident. There was no evidence of adverse medical conditions that affected the flightcrew, and they were not under the influence of, or impaired by, drugs or alcohol. The airplane had been maintained in accordance with applicable FARs and company operations specifications and maintenance procedures. Examination of the airplane's fuselage and wing structure, flight control systems, and powerplants disclosed no evidence of a malfunction that would have caused or contributed to the accident. Two fatigue cracks were found in the No. 2 engine pylon web.

The investigation found that the interaction of strong easterly winds with the mountains east of Anchorage was responsible for the production of moderate to severe mountain wave and mechanical turbulence. This turbulence, which occurred during the morning and afternoon on the day of the accident, was more intense a few thousand feet above the surface. It was found that winds from the east flow across and around the mountains, as well as through valleys in the mountains before reaching Anchorage. The interaction of the wind with the mountain valleys results in the acceleration of the wind speed due to the channeling effect of the valleys. The combination of these effects produces a complicated wind flow pattern and turbulence to the east of the airport in the lower layers of the atmosphere.

The Safety Board has previously investigated the possible effects of severe mountain-induced winds and turbulence on an airplane. Most recently, as a result of its investigation of an accident involving a B-737 on March 3, 1991,[2] the Safety Board recommended that the FAA:

A-92-57

Develop and implement a meteorological program to observe, document, and analyze potential meteorological aircraft hazards in the area of Colorado Springs, Colorado, with a focus on the approach departure paths of the Colorado Municipal Airport. This program should be made operational by the winter of 1992.

A-92-58

Develop a broader meteorological aircraft hazard program to include other airports in or near mountainous terrain, based on the results obtained in the Colorado Springs, Colorado, area.

In its letter of September 13, 1993, the FAA stated that it had tasked the National Oceanic and Atmospheric Administration's Forecast Systems Laboratory to organize a planning group to formulate a program plan to provide a definitive study of mountain-induced wind phenomena and their effect on aircraft in flight; and to develop initiatives to define and implement an awareness program to alert pilots to this potential hazard. The FAA's letter did not provide a timetable as to when the plan would be completed or a forecast as to when the implementation of a system to observe, document, and analyze potential meteorological aircraft hazards would begin.

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[2]Aircraft Accident Report--"United Airlines Flight 585, Boeing 737-291, N999UA, 4 Miles South of Colorado Springs Municipal Airport, Colorado Springs, Colorado, March 3, 1991" (NTSB-AAR-92/06)

The Safety Board finds that the accident involving flight 46E further amplifies the need for a better understanding of mountain-induced meteorological phenomena and their effects on aircraft. Therefore, the Safety Board reiterates Safety Recommendation A-92-58, which addresses that need. Additionally, the Safety Board believes that the FAA should develop and implement a meteorological program to observe, document, and analyze potential meteorological aircraft hazards in the area of Anchorage, Alaska, with a focus on the approach and departure paths of the Anchorage International Airport. Further, the Safety Board believes that the National Weather Service (NWS) should use the WSR-88D system at Anchorage to document mountain-generated wind fields in the Anchorage area. The WSR-88D system should also be used by the NWS to develop in greater detail low altitude turbulence forecasts.

According to the NWS at Anchorage, the strong wind events that produce significant turbulence occur about 15 times a year. Interviews with meteorologists and pilots in the Anchorage area indicated that the weather and turbulence on the day of the accident were fairly typical and that airplane operations are routinely carried out on similar days. Because the captain of flight 46E had operated B-747 airplanes out of Anchorage during similar turbulent conditions and because other airplanes were operating in the area at the time of the accident without difficulty, the Safety Board finds that there was no reason for the captain to have suspected that the airplane would be damaged during the climbout.

The investigation of this accident found that it is possible for a B-747 to be substantially damaged by the level of turbulence that was present on the day of the accident. The Safety Board does not believe that it would be reasonable to suspend operations at the airport during similar turbulence because, historically, aircraft have been able to operate safely at the airport during such conditions. However, according to the NWS at Anchorage, the most intense turbulence occurs near the mountains at low altitude. Therefore, by staying away from the mountains on departure, aircraft may lessen the chance of encountering severe turbulence. The Safety Board believes that the FAA should consider modifying the departure routes of aircraft at Anchorage during periods of moderate or severe turbulence in order to minimize an aircraft's encounter with mountain-induced low level turbulence.

Finite element computer analysis, based on the flight data recorder data, found that the maximum, combined loads, assuming maximum time phasing, were about 2.1 G to 3.0 G, which is close to or above the ultimate load (2.8 G) for the pylon in the lateral direction. The severe damage to the midspar fuse pin of the No.

1 engine pylon of the airplane indicates that the loads were sufficient to deform the pin and, therefore, were near the ultimate design load. Additionally, the computer analysis of the forward portion of the pylon structure showed that the presence of the fatigue crack in the firewall (at the point of the initiation of the pylon fracture) would reduce the stress capacity of the pylon by about 10 percent. The model predicted that in the presence of the cracked web, the No. 2 engine pylon would fail at a lateral load of between 2.35 G and 2.88 G, acting outboard.

The Safety Board notes that the design requirements specified in 14 Code of Federal Regulations (CFR) Part 25 allow manufacturers to analyze each axis of G loading independently when determining how strong a structure should be to withstand ultimate load. Manufacturers are not required to design the structure to withstand ultimate loads from multiple directions at the same time. Additionally, it was noted that Boeing's structural modification plan for the B-747 pylons would not significantly increase the lateral load-carrying ability of the structure.

The computer analysis found that encounters with reported severe turbulence can produce sufficient lateral loads to separate the pylon from the wing even without the presence of any cracks in the pylon web. The Safety Board believes that the wind fields and conditions that create severe turbulence are very complex and that areas or periods of extreme turbulence can be present at any time. Additionally, encounters with moderate and severe turbulence are considered relatively normal events by pilots and controllers, and operations are not curtailed by the forecast or pilot reports of severe turbulence. Therefore, it would appear that there is a safety-of-flight concern regarding the lateral design loads for engine pylons during severe turbulent conditions. However, moderating this concern is the fact that B-747 airplanes, as well as many other makes and models of airplanes, have been operating successfully for many years without engines or pylons separating from the wings solely because of turbulence. In general, it would appear that airline operating procedures and pilots actions have been effective in avoiding operations into extreme or very severe turbulence that could damage their airplanes. In view of the operating history of air carrier airplanes, with few reported cases of structural damage to engine pylons due to turbulence, the Safety Board believes that a requirement for structural modifications of all pylon structures is not warranted at this time. However, the Safety Board believes that, based upon the accident involving flight 46E, the FAA should modify the design load requirements of 14 CFR Part 25 to consider multiple axis loading and to more adequately consider the magnitude of the loads that can be experienced in turbulence conditions. The Safety Board also believes that if the FAA approves the Boeing-proposed B-747 engine pylon structural modifications, the modification should include increasing the lateral load capability of the structure. Additionally, the Safety Board believes that any future structural modifications of existing engine pylons should consider multiple axis loading and the feasibility of increasing the lateral strength of the pylon structure.

The forward firewall extends from nacelle station (NS) 128.0 to NS 180.0. Airworthiness Directive (AD) 82-22-02 requires a visual inspection of the very forward portion of this firewall (NS 128 to NS 135, adjacent to the front engine mount bulkhead) because of cracks that have been found in this area. In addition, at the time of the accident, there were Boeing-recommended inspections of the firewall web from NS 163 to NS 180. However, the fatigue crack that was found in the firewall of the No. 2 engine pylon of the accident airplane was not within these inspection areas. There were no required or recommended inspections of this area at the time of the accident. Recently, Boeing issued Service Bulletin (SB) 747-54-2160, which addresses inspecting the firewall web from NS 135.6 to NS 163, which would cover the area where the fatigue crack was found.

The fatigue cracking found on flight 46E's No. 2 engine pylon midspar web probably resulted from sheet bending due to flexing or vibration of the web material. The Safety Board believes that the crack probably would have been detected if there had been a requirement to inspect this area. Therefore, to reduce the likelihood of similar failures of the B-747 pylon, the Safety Board believes that the FAA should require all operators to inspect the entire pylon forward firewall web at specific flight hour intervals.

As a result of its investigation of this accident, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Develop and implement a meteorological program to observe, document, and analyze potential meteorological aircraft hazards in the area of Anchorage International Airport, Anchorage, Alaska, with an emphasis on the approach and departure paths of the airport. (Class II, Priority Action) (A-93-136)
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> Amend the design load requirements of 14 CFR Part 25 to consider multiple axis loads encountered during severe turbulence. (Class III, Longer Term Action) (A-93-137)

Require the Boeing-proposed B-747 engine pylon structural modification program to include increasing the lateral load capability of the pylon structure. (Class II, Priority Action) (A-93-138)

Require any future structural modifications of existing engine pylons to consider multiple axis loading. (Class II, Priority Action) (A-93-139)

Issue an Airworthiness Directive to require compliance with Boeing Service Bulletin 747-54-2160. (Class II, Priority Action) (A-93-140)

Consider the necessity and feasibility of requiring the modification of the aircraft departure routes at Anchorage International Airport during periods of moderate or severe turbulence to minimize the potential of aircraft encountering mountain-induced low level turbulence. (Class II, Priority Action) (A-93-141)

Additionally, the Safety Board reiterates Safety Recommendation A-92-58:

Develop a broader meteorological aircraft hazard program to include other airports in or near mountainous terrain, based on the results obtained in the Colorado Springs, Colorado, area.

Also the Safety Board issued Safety Recommendation A-93-142 to the National Weather Service.

Chairman VOGT, Vice Chairman COUGHLIN, and Members LAUBER, HART, and HAMMERSCHMIDT concurred in these recommendations.

By: Carl W. Vogt
Chairman