Engine failure of flight 191 engineering essay

The loss of the engine by itself should not have been enough to cause the accident.[12] Flight 191 would have been perfectly capable of returning to the airport using its remaining two engines, as the DC-10 is capable of staying airborne with any single engine out of operation. However, several other factors combined to cause a catastrophic loss of control.

The engine separation had severed the hydraulic lines that controlled the aircraft's leading-edge wing slats (retractable devices that decrease a wing's stall speed during takeoff and landing). The damage to the lines caused a loss of hydraulic pressure, which in turn led to uncommanded retraction of the outboard slats in the left wing.[1] Unlike other aircraft designs, the DC-10 did not include a separate mechanism to lock the slats in place.[1]

Investigators examined the flight data recorder (FDR) and conducted wind tunnel tests and flight simulator tests to understand the trajectory of flight 191 after the engine detached and the slats retracted. These tests established that the damage to the wing leading edge and retraction of the slats increased the stall speed of the left wing from 124kt to 159kt.[1]

Comparison of the FDR data and the simulator tests showed that the pilots of flight 191 had followed the procedure for engine failure at take-off. This procedure called for the captain to go to VHYPERLINK " http://en. wikipedia. org/wiki/V_Speeds#Other_reference_speeds" 2 (standard safety takeoff speed) which for flight 191 was 153kt, 6kt below the stall speed.[1] At the time the engine fell off the aircraft, flight 191 was already travelling at 165kt, safely above the stall speed. Thus, by slowing the aircraft to 153kt in accordance with the emergency procedure, the pilots inadvertently induced

the stall which proved fatal. Following this accident, McDonnell Douglas revised the procedure, advising that if the aircraft was already flying faster than V2 plus 10kt the pilots should maintain a margin of 10kt above V2.[1]

The DC-10 incorporates two warning devices which might have alerted the pilots to the impending stall: the slat disagreement warning light which should have illuminated after the uncommanded retraction of the slats, and the stall warning system (stick-shaker) which activates close to the stall speed. Unfortunately, both of these warning devices were powered by an electric generator driven by the no. 1 engine; following the loss of that engine, they both became inoperative.[1]

[edit] Engine separation

An FAA diagram of the DC-10 engine and pylon assembly indicating the failed aft pylon attach fitting.

From an examinaton of the detached engine, the NTSB concluded that the pylon attachment had been damaged before the crash.[1] Investigators looked at the plane’s maintenance history and found that its most recent service was eight weeks before the crash, in which engine number one had been removed from the aircraft, however the pylon, the rigging holding the engine onto the wing, had been damaged during the procedure. The original procedure called for removal of the engine prior to the removal of the engine pylon, but American Airlines had begun to use a procedure that saved approximately 200 man-hours per aircraft and “ more importantly from a safety standpoint, it would reduce the number of disconnects (i. e., hydraulic and fuel lines, electrical cables, and wiring) from 72 to 27.”[1]

The new procedure involved mechanics removing the engine with the pylon as one unit, rather than the engine, and then the pylon. A large forklift was used to support the engine while it was being detached from the wing – a procedure that was found to be extremelly difficult to execute successfully, due to difficulties with holding the engine assembly straight while it was being removed.

The field service representative from the manufacturer, McDonnell-Douglas, said it would “ not encourage this procedure due to the element of risk” and had so advised American. However, McDonnell-Douglas “ does not have the authority to either approve or disapprove the maintenance procedures of its customers.”[1]

The accident investigation also concluded that the design of the pylon and adjacent surfaces made the parts difficult to service and prone to damage by maintenance crews. The NTSB reported that there were two different approaches to the one-step procedure: using an overhead hoist or using a forklift. United Airlines used a hoist; American and Continental Airlines used a forklift. According to the NTSB, all the cases “ wherein impact damage was sustained and cracks found involved the use of the forklift.”[1]

Under the procedure American used, if the forklift was in the wrong position, the engine would rock like a see-saw and jam against the pylon attachment points. The forklift operator was guided by hand and voice signals; the position had to be spot-on or could cause damage. Management was aware of this. The modification to the aircraft involved in Flight 191 did not go smoothly. Engineers started to disconnect the engine and pylon, but

changed shift halfway through. When work continued, the pylon was jammed on the wing and the forklift had to be repositioned. This was important evidence because, in order to disconnect the pylon from the wing, a bolt had to be removed so that the flange could strike the clevis. The procedure used caused an indentation that damaged the clevis pin assembly and created an indentation in the housing of the self-aligning bearing, which in turn weakened the structure sufficiently to cause a small stress fracture. The fracture went unnoticed for several flights, getting worse with each flight. During Flight 191's takeoff, enough force was generated to finally cause the pylon to fail. At the point of rotation, the engine detached and was flipped over the top of the wing.

[edit] Conclusion

The findings of the investigation by the National Transportation Safety Board (NTSB) were released on December 21, 1979:[1]

The National Transportation Safety Board determines that the probable cause of this accident was the asymmetrical stall and the ensuing roll of the aircraft because of the uncommanded retraction of the left wing outboard leading edge slats and the loss of stall warning and slat disagreement indication systems resulting from maintenance-induced damage leading to the separation of the No. 1 engine and pylon assembly at a critical point during takeoff. The separation resulted from damage by improper maintenance procedures which led to failure of the pylon structure.

Contributing to the-cause of the accident were the vulnerability of the design of the pylon attach points to maintenance damage; the vulnerability of the

design of the leading edge slat system to the damage which produced asymmetry; deficiencies in Federal Aviation Administration surveillance and reporting systems which failed to detect and prevent the use of improper maintenance procedures; deficiencies in the practices and communications among the operators, the manufacturer, and the FAA which failed to determine and disseminate the particulars regarding previous maintenance damage incidents; and the intolerance of prescribed operational procedures to this unique emergency.

The NTSB determined that the damage to the left wing engine pylon had occurred during an earlier engine change at the American Airlines aircraft maintenance facility in Tulsa, Oklahoma on March 29 and 30, 1979.[1] The evidence came from the flange, a critical part of the pylon assembly.

[edit] Aftermath

First responders survey the Flight 191 crash site in Des Plaines, Illinois.

Problems with DC-10s were discovered as a cause of the accident, including deficiencies in both design specifications and maintenance procedures which made damage very likely. In response to this incident, American Airlines was fined by the United States government $500, 000 for improper maintenance procedures[12].

Two weeks after the accident, on June 6, the FAA ordered all DC-10s to be grounded until all problems were solved. The ban was lifted on July 13.[13]

The crash of another DC-10 in November 1979, Air New Zealand Flight 901, would only add to the DC-10’s negative reputation at the time – however,

Flight 901 was caused by several human and environmental factors not related to the airworthiness of the DC-10, and the aircraft was later completely exonerated in that accident. Although McDonnell Douglas employees participated in an “ I’m proud of the DC-10” campaign, the company’s shares fell more than 20% following the crash of Flight 191. In 1997, the McDonnell Douglas company was taken over by its rival, Boeing.

Despite the safety concerns, the DC-10 went on to outsell its closest competitor, the Lockheed L-1011 TriStar, by nearly 2 to 1. This was due to the L-1011’s launch being delayed, the introduction of the DC-10-30 long range model without a competing TriStar variant, and the DC-10 having a greater choice of engines (the L-1011 was only available with Rolls-Royce engines, while the DC-10 could be ordered with General Electric or Pratt HYPERLINK “ http://en. wikipedia. org/wiki/Pratt_&_Whitney”&HYPERLINK “ http://en. wikipedia. org/wiki/Pratt_&_Whitney” Whitney engines). The DC-10 program also benefited from obtaining a U. S. Air Force contract to develop a long-range refueller, which culminated in the KC-10 Extender. Lockheed had no such support for the TriStar, and halted production in 1982.

NTSB investigation

The crash of flight 191 brought fierce criticism from the media because it was the fourth fatal accident involving a DC-10 at the time. Six hundred and twenty-two people had died in DC-10 accidents, including flight 191. As the weather was perfect for flying and there was no indication that a flock of birds or another plane caused the crash, the remains of engine #1 raised serious concerns of the safety of the DC-10. The separated engine was not the only concern, as the public wanted to know whether the detached engine

was the only cause of the crash. Investigators wondered if a fire was possibly the cause, as this was backed up by testimony from air traffic controller Ed Rucker who said he saw a ‘ flash’ from the wing. This raised concerns that 191 was the result of a terrorist attack. Sixty witnesses who saw the plane on the runway ruled out a bomb, as they all saw engine #1 swing forward then flip up and over the top of the wing, which pointed to structural failure as the cause.

The findings of the investigation by the National Transportation Safety Board (NTSB) were released on December 21, 1979. It revealed the probable cause to be attributable to damage to the left wing engine pylon that occurred during an earlier engine change at American Airlines’s aircraft maintenance facility in Tulsa, Oklahoma on March 29 and 30, 1979. cite web | url= http://amelia. db. erau. edu/reports/ntsb/aar/AAR79-17. pdf | title= NTSB (National Transportation Safety Board) Report] Evidence came from the flange, a critical part of the pylon assembly. It was revealed to be damaged before the crash, and investigators looked at the plane’s maintenance history and found it was serviced eight weeks before the crash. The pylon was damaged due to an ill-thought-out engine removal procedure. The original procedure called for removal of the engine prior to the removal of the engine pylon. To save time and costs, American Airlines, without the approval of McDonnell Douglas, had begun to use a faster procedure. They instructed their mechanics to remove the engine with the pylon all together as one unit. A large forklift was used to support the engine while it was being detached from the wing. This procedure was extremely difficult to execute

successfully, due to difficulties with holding the engine assembly straight while it was being removed.

This method of engine-pylon removal was used to save man hours and was encouraged despite differences with the manufacturer’s specifications on how the procedure was supposed to be performed. The accident investigation also concluded that the design of the pylon and adjacent surfaces made the parts difficult to service and prone to damage by maintenance crews. According to the History Channel, cite video

title = The Crash of Flight 191

url = http://store. aetv. com/html/product/index. jhtml? id= 71451

publisher = The History Channel

publisherid = AAE-71451

medium = DVD] United Airlines and Continental Airlines were also using a one-step procedure. After the accident, cracks were found in the bulkheads of DC-10s in both fleets.

The procedure used for maintenance did not proceed smoothly. If the forklift was in the wrong position, the engine would rock like a see-saw and jam against the pylon attachment points. The forklift operator was guided by hand and voice signals; the position had to be spot-on or could cause damage, but management was unaware of this. The modification to the aircraft involved in flight 191 did not go smoothly; engineers started to disconnect the engine and pylon but changed shift halfway through; when

work continued, the pylon was jammed on the wing and the forklift had to be re-positioned. This was important evidence because, in order to disconnect the pylon from the wing, a bolt had to be removed so that the flange could strike the clevis. The procedure used caused an indentation that damaged the clevis pin assembly and created an indentation in the housing of the self-aligning bearing, which in turn weakened the structure sufficiently to cause a small stress fracture. The fracture went unnoticed for several flights, getting worse with each flight that the plane had taken. During flight 191's takeoff, enough force was generated to finally cause the pylon to fail. At the point of rotation, the engine detached and was flipped over the top of the wing.

The loss of the engine by itself should not have been enough to cause the accident. During an interview on Seconds From Disaster, Former NTSB investigator Michael Marx mentioned there were other incidents where the engine fell off, yet they landed without incident. Flight 191 would have been perfectly capable of returning to the airport using its remaining two engines, as the DC-10 is capable of staying airborne with any single engine out of operation. Unfortunately, several other factors combined to cause a catastrophic loss of control.

The separation of the engine severed electrical wiring and hydraulic lines which were routed through the leading edge of the wing. The damage to the lines caused a loss of hydraulic pressure, which in turn led to uncommanded retraction of the outboard slats in the port wing. The DC-10 design included a back-up hydraulic system which should have been enough to keep the slats in place; however, both lines are too close together, a design also used on the DC-9. There should have been enough fluid to keep the slats extended,

so investigators wanted to know why they were never re-extended by the pilot. The answer came from the end of the recording on the CVR. The number 1 engine powered both the recorder and the slat warning system, which left the pilot and co-pilot with no way of knowing about the position of the slats. Investigators examined the FDR to see what occurred after the engine detached. The procedure called for the captain to go to V2 which he did perfectly, but investigators found that it said nothing about incidents where the speed was already above V2, as it was in this case. Therefore, the pilot had to reduce speed. Simulator tests were done to see if this made a difference; 13 pilots followed the procedure 70 times and not one was able to recover. The NTSB concluded that reducing speed when the slats are back may actually have made it more difficult for the pilot to recover control of the aircraft. When a DC-10 is about to stall it gives two warnings: The first is the stick-shaker which causes the yoke to vibrate, and the second is a warning light that flashes. These combined warnings should have alerted the pilots to increase speed immediately. American Airlines had chosen to have the stick-shaker on the pilot’s side only, but the stick-shaker did not operate because it was powered by the missing left engine. In the event of an engine failure, it is possible for the flight engineer to switch the pilot’s controls to a backup power supply. However, investigators determined that in order for him to access the necessary switch, the engineer would have had to unfasten his seat belt, stand up, and turn around.

The DC-10 hit the ground with a bank of 112°, and at a nose-down attitude of 21°. The NTSB concluded that given the circumstances of the situation, the pilots could not be reasonably blamed for the resulting accident.

In his book “ Blind Trust”, [cite book | title = Blind Trust | last= Nance | first= John J. | authorlink= John J. Nance | publisher = William Morrow & Co | isbn = 0-688-05360-2 | year = 1987] John J. Nance argues that the 1978 Airline Deregulation Act caused havoc and induced cost-cutting in the industry, producing a serious erosion of the margin of safety for passengers. Nance argues that the industry “ reverted from an industry under partial surveillance to an industry running on the honor system”.

Aftermath

Problems with DC-10s were discovered as a cause of the accident, including deficiencies in both design specifications and maintenance procedures which made damage very likely. Since the crash happened just before a Western Airlines DC-10 crashed in Mexico City and five years after a Turkish Airlines DC-10 crashed near Paris, the FAA quickly ordered all DC-10s to be grounded until all problems were solved. The result of the problem-solving was an arguably more efficient and safe DC-10.

The US government fined American Airlines $500, 000 for improper maintenance procedures, but the insurance settlement for the replacement of the aircraft gave American Airlines $25, 000, 000 beyond the amount of the fine. Fact| date= June 2007

Although the company’s employees participated in an “ I’m proud of the DC-10” campaign, McDonnell Douglas shares fell more than 20% following the crash of Flight 191. The DC-10 itself had a bad reputation, but ironically it was often caused by poor maintenance procedures, and not design flaw. In

1997 the McDonnell Douglas company was taken over by its rival, Boeing, which moved its corporate headquarters from Seattle to Chicago.

Despite the safety concerns, the DC-10 went on to outsell its closest competitor, the Lockheed L-1011, by nearly 2 to 1. This was due to the L-1011’s launch being delayed and the DC-10 having a greater choice of engines (the L-1011 was only available with Rolls-Royce engines, while the DC-10 could be ordered with General Electric or Pratt & Whitney engines).