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BOEING

Subject: El Al 747-200F Accident - Amsterdam - October 4, 1992

Reference: Netherlands Aviation Safety Board
Aircraft Accident Report 92-11

Dear Mr. Wolleswinkel:

The Netherlands Aviation Safety Board Final Report included several safety recommendations. The recommendations and Boeing's response are as follows:

4.1 Redesign the B747 pylon structure including attachment to engine and wing. All SBs and ADs should be terminated after the redesign.

The 747/747-400 nacelle strut structural redesign will upgrade the strut and strut-to-wing attachments on the entire 747 fleet. This new design, which incorporates a redundant load path, significantly improves the load carrying capability of the strut-to-wing attachments. The redesigned structure will be similar to the design used on Boeing's newer airplane models (757, 767 and 777). All strut-related Airworthiness Directives and all significant Service Bulletins will be terminated by the redesign. The redesign was implemented in production during 1994.

The features of the redesigned strut and strut-to-wing attachment will be incorporated into the 747/747-400 fleet through a Nacelle Strut Structural Modification Program. Because of the impact this modification has on the 747/747-400 fleet, airline participation was requested during the define and design phases of the modification program. As a result, the 747/747-400 Structures Task Group (STG) was selected by the operators to represent the airline industry. The STG members worked closely with Boeing and have reviewed the design for this modification. In addition, the STG members have provided recommendations to accomplish other service bulletins that would reduce the dependence on non-routine inspections and improve the durability of the strut-to-wing attachment.

An all-operators meeting to review the Strut Structural Modification Program was held in Seattle on May 11-12, 1994. A copy of the presentation material from this meeting is enclosed.

4.2 The redesign program for the pylon should include a full-scale fatigue and fail-safe test.

A full-scale fatigue test of a 747 strut incorporating the changes identified by the redesign will begin later this year. Currently, plans call for a 72,000 flight cycle fatigue test followed by an additional series of fatigue cycles with major load path members disconnected to validate damage tolerance characteristics.

4.3 A large scale inflight fleet-wide fatigue load measurement program should be carried out, both on wing, fuselage, and fin mounted engines in order to establish more realistic load spectra for fatigue evaluation.

An extensive flight load survey, including in-service airplanes, has been conducted to better understand the loads at the engine. In addition, one airplane was extensively instrumented at the strut-to-wing attachments and flight tested under simulated operational conditions. The results of these flight load measurements have been used to define the static and fatigue loads for the strut redesign. Additionally, the findings of the fatigue load studies will be used to update the Supplemental Structural Inspection Document (SSID) for other Boeing models.

4.4 Review present methods of controlling structural integrity, such as non-destructive inspection techniques and airworthiness directive requirements, in the current design B747 pylon assembly.

The strut redesign will reduce dependence on non-routine inspections. The redesign provides limit load capability for single failure where practical. Post-modification service bulletins will reflect external and internal visual inspections at the appropriate threshold and check intervals. Overhaul programs will assure continued damage tolerance for those areas where full fail-safe capability is not practical.

4.5 If a structural design concept is used as the basis for the certification of another design, in-service safety problems for both designs should be cross-referenced.

In addition to regular reviews of in-service problems, Boeing has initiated an Airplane Safety Awareness Process (ASAP) to identify potential safety problems. Service-related problems and potential airplane safety issues are cross referenced to assure proper corrective action with regard to airworthiness or safety concerns.

4.6 Evaluate and where necessary improve the training and knowledge of flight crews concerning factors affecting aircraft control when flying in asymmetrical conditions such as with one or more engines inoperative including:
- advantages and disadvantages of direction of turn
- limitation of bank;
- use of thrust in order to maintain controllability;

4.7 Evaluate and where necessary improve the training and knowledge of flight crews in cockpit resource management in order to prepare them for multiple systems failures, conflicting checklist requirements and other beyond abnormal situations.

4.8 Expand the information on inflight emergencies in appropriate guidance material to include advice how to insure that pilots and air traffic controllers are aware of the importance to exchange information in case of inflight emergencies. The use of standard phraseology should be emphasized.

Boeing has revised the Flight Crew Training Manuals to provide guidelines for situations which are beyond the scope of non-normal procedures. Topics included are basic aerodynamic principles and airplane systems, flight path control, checklists procedures, communications, damage assessment and airplane handling evaluation and approach and landing. Copies of the pertinent pages from the B747 Flight Crew Training Manual are enclosed as examples.

4.9 Evaluate and where necessary develop common guidelines on emergency procedures and phraseology to be used between ATC, Fire Brigade, Airport Authorities and RCC.

No comment

4.10 Expand the training of pilots and ATC personnel to include the awareness that in the handling of emergency situations not only the safety of airplane/passengers but also the risk to third parties especially residential areas should be considered.

The following is an excerpt from the B747 Flight Crew Training Manual mentioned above: "When encountering an event of the type described above, the flight crew's first consideration should be to maintain or regain full control of the airplane and establish an acceptable flight path... The objective is to take whatever action is necessary to control the airplane and maintain a safe flight path. Even in a worst case condition where it is not possible to keep the airplane flying and ground contact is imminent, a "controlled crash" is a far better alternative than uncontrolled flight into terrain."

4.11 Review design philosophy of fire warning systems, to preclude false warnings upon engine separation.

The 747 fire detection system consists of four-dual loop elements connected in series in the engine nacelle. The signal from these elements is evaluated to determine whether it is initiated by a fire or a system fault. The logic is that two faults result in a fire signal, a logic architecture was selected to ensure an engine case burn through condition would be annunciated as a fire. Service experience has shown the alternative logic, i.e., two system faults result in a failure signal, to be incapable of responding to a very intense, localized fire.

Flight crew procedure is the same for an engine fire, severe engine damage or engine separation, i.e., shut down the engine and discharge the fire extinguishing bottle(s). This ensures that the wing front spar fuel shutoff valve is closed, thereby terminating fuel flow and improving airplane safety.

4.12 Review flight control design to ensure that flight control surfaces do not contribute adversely to airplane control in case of loss of power to a control surface.

The 747/747-400 control surfaces are divided into two groups: Primary (aileron, elevator, rudder, and lateral control spoiler) and secondary (speedbrakes and stabilizer). All flight controls are driven by hydraulically powered actuators.

Each aileron is powered by a dual tandem actuator supplied by two separate hydraulic sources. With loss of hydraulic power to an outboard aileron, the maximum float angle is approximately 10 degrees trailing edge up. This float angle causes a rolling moment equivalent to approximately 20% of the two hydraulic systems inoperative full wheel rolling moment capability. Flight tests of the 747-100 demonstrated acceptable control characteristics with unpowered outboard aileron during approaches to stall with hydraulic systems 1 and 2, or 3 and 4 inoperative. Loss of power to an inboard aileron results in even smaller rolling moment than the outboard aileron.

The elevator control system consists of four elevators. Dual tandem actuators supplied by two separate hydraulic sources power the inboard elevators and dual tandem actuators with a single cylinder operating power the outboards. The inboard and outboard elevators are driven by separate actuators, but the outboard elevator control valves are slaved to the inboard elevator surfaces. Loss of hydraulic power to an elevator results in a float angle of between zero and three degrees trailing edge up, which results in a stabilizer trim change of less than half a unit. Flight tests of the 747-100 demonstrated acceptable control characteristics with unpowered inboard and outboard elevator during approaches to stall, wind-up turns, and landings. Simulated landings were successfully demonstrated during flight tests of the 747-400 by flying an approach and a landing flare at altitude.

The rudder control system consists of an upper and a lower rudder, each separately powered by two hydraulic systems. Loss of hydraulic power to a single rudder leaves the other rudder powered by the remaining two hydraulic systems. Flight tests of the 747-100 demonstrated acceptable control characteristics with unpowered upper or lower rudder during engine out trims and full rudder sideslips with hydraulic systems 1 and 3, or 2 and 4 inoperative.

Flight spoilers are each powered by a single hydraulic system. The hydraulic system layout for the twelve spoilers is arranged so that loss of power to the spoilers is symmetric. Spoiler float was checked during 747-100 flight test by, in turn, deactivating each hydraulic system, exercising the control wheel, and then with the wheel centered, noting the spoiler position. No spoiler had deflected more than 2 inches at the trailing edge.

Two stabilizer trim control modules powered by hydraulic systems 2 and 3 control the stabilizer trim system. Loss of hydraulic power to these two modules results in the stabilizer position being locked by a braking system. Flight tests of the 747-100 demonstrated acceptable pitch characteristics with unpowered stabilizer during landings with hydraulic systems 2 and 3 inoperative and the stabilizer set at a cruise setting.

The effects of each of these failure modes has been included in simulator studies and all possible failure combinations were considered in the basic airplane design.

4.13 Fire resistance of DFDR and CVR should be improved.

Solid state DFDR and CVR devices are now available. Solid state DFDRs are basic Seller Furnished Equipment (SFE). Alternate solid state DFDRs and solid state CVRs are offered as Buyer Furnished Equipment (BFE).

All recorders are developed to meet or exceed regulations in effect at the time of airplane delivery. At this time, DFDRs meet or exceed FM TSO c124 and EUROCAE ED-55. At this time, CVRs meet or exceed FM TSO c123 and EUROCAE ED-56. Boeing is not aware of the availability of a CVR which complies with EUROCAE ED-56-A, although some CVRs are being developed to meet or exceed crash survivability requirements as specified in ED-56-A. Boeing will offer BFE CVRs that meet ED-56-A when they become available.

The SFE DFDR has been tested by the supplier of the DFDR to successfully survive a high-temperature burn of 1100 degrees C. for 60 minutes (although ED-55 only requires 30 minutes). More than 95% of 747-400 and 767 airplanes will be delivered with the SFE solid state DFDR.

Customer airlines have been advised of the availability and advantages of solid state recorders. However, alternative tape BFE DFDRs and BFE CVRs have been selected by some customers and are still being delivered.

4.14 Investigate the advantages of installation cameras for external inspection of the airplane from the flightdeck.

Boeing is monitoring closely the progress of a customer airline flight test of a video installation which permits external inspection of the airplane from the flightdeck. In addition, an internal Boeing study is considering external video for use during ground maneuvering. The technical and operational issues concerning the use of such devices are significant. Boeing is proceeding carefully in determining whether a video system is value added to existing well-proven design.

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If you have any additional questions or require clarification of any of the above information, please contact the undersigned.

Very truly yours,

FLIGHT TEST

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Enclosure: A. 747 Nacelle Strut Structural Modification Program Meeting 2, May 11-12, 1994, Presentation Material Booklet.
B. 747 Flight Crew Training Manual, Pages 1.23 thru 1.26, dated August 16, 1993

cc: without enclosures
Mr. Bob Benzon, United States National Transportation Safety Board (NTSB)
Mr. Bud Donner, United States Federal Aviation Agency (FAA)