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NATIONAL TRANSPORTATION SAFETY BOARD

WASHINGTON, D.C.

Critical Design Review, Executive Summary

B737 FLIGHT CONTROL CRITICAL DESIGN REVIEW

- EXECUTIVE SUMMARY -

MAY 3, 1995

OVERVIEW

Since 1967 the Boeing 737-100/-200 series airplanes have accumulated nearly 43 million flight hours and the -300/-400/-500 series airplane nearly 20 million flight hours. During that time, there have been 55 hull losses within the whole series of B737 models, none of which have yet been attributed to flight control malfunctions. The hull loss rate varies between 1.15 and 0.53 accidents per million departures and represents one of the best safety records in the fleet of transport category airplanes.

Despite this safety record, the USAIR B737 accident near Pittsburgh and the United B737 accident near Colorado Springs raised questions about the flight control systems. During the Colorado Springs accident investigation a rudder deflection was evaluated and concluded to not be likely to have caused the accident. Even after the investigation of the Colorado Springs accident was closed by the National Transportation Safety Board (NTSB), the FAA continued to review the events of that accident to see if the airplane flight controls in any way contributed to its cause.

OVERVIEW (CONT.)

In October 1994, the FAA chartered a Critical Design Review (CDR) of the B737 flight controls to determine if anything had been overlooked regarding the investigation of the recent accidents. The CDR team concluded that the B737 complied with the applicable airworthiness requirements (FARs) and the original certification tests were typical of those conducted at the time of its certification to show compliance. The team performed a hazard assessment to identify anything, regardless of its likelihood of occurrence, that could have contributed to a flight control malfunction. The focus of the CDR was on the alternative means to control the airplane in the event of failures or malfunctions. Consequently, some design, maintenance and pilot training recommendations have been made to improve the fault tolerance of the B737 aileron and rudder control systems. No safety issue has been found that requires immediate corrective action.

The CDR team developed recommendations dealing with the identified issues. In some cases the recommendations are beyond the certification requirements for the B737 and other airplane models of comparable design, but the CDR team believes they should be implemented on the B737 to enhance its already acceptable level of safety. In response to the recommendations, the FAA will develop an implementation plan to initiate and track appropriate actions for these recommendations.

Although the CDR team was not involved in the investigation of the USAIR B737 accident near Pittsburgh or the United B737 accident near Colorado Springs, the team does not believe they have found any cause(s) for those accidents. This document provides the essential information contained in the final report of the critical design review.

BACKGROUND

- OBJECTIVE OF THE REVIEW WAS TO ASSESS CONTINUED OPERATIONAL SAFETY OF THE B737 FLIGHT CONTROL SYSTEM AND RECOMMEND CORRECTIVE ACTION FOR ANY DEFICIENCIES DISCOVERED

- THE TEAM EXAMINED ALL ASPECTS OF THE LATERAL AND DIRECTIONAL FLIGHT CONTROL SYSTEM

- DESIGN, MAINTENANCE AND OPERATIONAL FACTORS WERE EVALUATED

CDR - A UNIQUE EFFORT

- TEAM NOT PREVIOUSLY INVOLVED IN B737 CERTIFICATION
- INCLUDED PEOPLE OUTSIDE OF FAA - NTSB, USAF, TRANSPORT CANADA
- TEAM LOOKED ONLY AT WHAT FAILURES AND MALFUNCTIONS OF THE CONTROL SYSTEM WERE PHYSICALLY POSSIBLE - HAZARD ASSESSMENT
- TEAM DID NOT LOOK AT THE LIKELIHOOD OF THOSE EVENTS OCCURRING - CLEARLY SOME HAVE NEVER OCCURRED IN SERVICE
- CONTINUING ACTIVITY, AS A RESULT OF THE RECOMMENDATIONS, WILL LOOK AT EVENT PROBABILITIES

CONSERVATIVE ASSUMPTIONS

- UTILIZED QUALITATIVE HAZARD ASSESSMENT PROCESS.
- ASSUMED THAT "NORMAL FLIGHT ENVELOPE" OR "CONTROL POSITION NORMALLY ENCOUNTERED" SHOULD CONSIDER THE POTENTIAL FOR A FLIGHT CONTROL SURFACE TO FAIL OR JAM WHEN AT FULL LIMIT DEFLECTION.
- A FAILURE CONDITION IS CONSIDERED A HAZARD WHEN CONTINUED SAFE FLIGHT AND LANDING IS DOUBTFUL.
- APPLIED "LATENT FAILURES" GUIDANCE AS PROVIDED BY FAA ADVISORY CIRCULAR 25.1309-1A - NOT WRITTEN WHEN B737 ORIGINALLY CERTIFIED
- ASSUMED THAT "CONTINUED SAFE FLIGHT AND LANDING" INCLUDES CONSIDERATION FOR THE PILOTS' WORKLOAD, STRENGTH, AND SKILL REQUIREMENTS IN MAINTAINING CONTINUOUS CONTROL OF THE AIRPLANE.
- ASSUMED WORST CASE REACTION OF THE FLIGHT CREW TO IDENTIFIED FAILURES AND MALFUNCTIONS.

PROCESS

- AFTER COMPLETION OF AIRPLANE FAMILIARIZATION AND REVIEW OF THE FAILURE ANALYSIS, TEAM IDENTIFIED SINGLE AND LATENT FAILURES OF CONCERN.

- IDENTIFIED AND EVALUATED ADEQUACY OF ALTERNATE MEANS FOR RESOLVING THE CONSEQUENCE OF THE FAILURE AND CONTROLLING THE AIRPLANE.

- REVIEWED SERVICE HISTORY OF FLIGHT CONTROL SYSTEM COMPONENTS AND IDENTIFIED DESIGN MODIFICATION AND MAINTENANCE REQUIREMENTS IN SUPPORT OF CONTINUED OPERATIONAL SAFETY.

- REVIEWED THE ACCIDENT HISTORY OF THE AIRPLANE AND PREVIOUS NTSB RECOMMENDATIONS

PROCESS (CONT.)

- TEAM ACTIVITIES-

1. FLIGHT CONTROL SYSTEM FAMILIARIZATION INCLUDING HANDS-ON EXPERIENCE WITH NEW AND USED FLIGHT CONTROL SYSTEM COMPONENTS

2. CONDUCTED EXTENSIVE FLIGHT SIMULATOR EXERCISE

3. REVIEWED B737 FLIGHT CONTROL SYSTEM FAILURE ANALYSIS

4. CONDUCTED INTERVIEWS OF COMPONENT MANUFACTURERS AND FLIGHT CONTROL SYSTEM EXPERTS, E.G., PARKER, HONEYWELL, DOUGLAS AIRCRAFT COMPANY, TRANSPORT AIRPLANE DIRECTORATE ENGINEERS

5. VISITED REPAIR STATIONS AND INFORMALLY INSPECTED COMPONENTS HAVING DIRECT IMPACT ON THE CONTINUED OPERATIONAL SAFETY OF B737 FLIGHT CONTROL SYSTEM, E.G., FORTNER, TRAMCO

BOEING FLIGHT SIMULATOR SCENARIOS

- RUDDER/AILERON TRIM RUNAWAYS OPPOSED BY THE AUTOPILOT
- LATERAL VERSUS DIRECTIONAL CONTROL POWER INCLUDING RUDDER MAXIMUM DEFLECTION
- FLIGHT WITH ZERO OR ONE-HALF AILERON/RUDDER FEEL FORCE
- CONTROL THROUGH THE AILERON TRANSFER MECHANISM WITH AILERONS JAMMED AT ONE-HALF AND FULL DEFLECTION
- FLIGHT WITH ONE OR TWO FLIGHT SPOILERS STUCK UP ON THE SAME SIDE
- FLIGHT WITH THE #2 SLAT RETRACTED AND FLAPS EXTENDED TO 1, 5, 15, 25 AND 40, COMBINED WITH A MAXIMUM FLAP ASYMMETRY BETWEEN FLAPS 15 AND 25

RESULTS

- THE B737 MEETS ALL CERTIFICATION REQUIREMENTS

- NO DESIGN DEFECTS WERE IDENTIFIED THAT WOULD REQUIRE IMMEDIATE CORRECTIVE ACTION

- NO SPECIFIC SCENARIO(S) IDENTIFIED THAT COULD EXPLAIN EITHER OF THE ACCIDENTS

- 27 RECOMMENDATIONS TO ENHANCE AN ALREADY SAFE DESIGN OF THE B737 AND IMPROVE THE CERTIFICATION PROCESS

SUMMARY of RECOMMENDATIONS

- 27 RECOMMENDATIONS -

1. ENHANCED ALTERNATE MEANS TO CONTROL AIRPLANE FLIGHT PATH --- (6 ITEMS)

2. ENHANCED FLIGHT CREW TRAINING FOR RESPONSE TO FAILURES AND FLIGHT PATH UPSET --- (4 ITEMS)

3. IMPROVED DESIGN AND PROTECTION OF FLIGHT CONTROL COMPONENTS --- (6 ITEMS)

4. IMPROVED MAINTENANCE OF FLIGHT CONTROL COMPONENTS AND ASSEMBLIES --- (7 ITEMS)

5. IMPROVED SURVEILLANCE OF DESIGN, MANUFACTURE AND REPAIR OF REPLACEMENT PARTS FOR FLIGHT CONTROL COMPONENTS --- (3 ITEMS)

6. COMMITMENT TO CONTINUE ACCIDENT INVESTIGATION EFFORTS, BUILDING UPON THE DATA DEVELOPED BY THE CDR TEAM--- (1 ITEM)

IMPLEMENTATION PLAN

The FAA is developing a plan for implementing the B737 Critical Design Review, "Recommendations for FAA Action" contained in the CDR Report dated April 25, 1995. The Plan will be provided as a separate document, B737 FLIGHT CONTROL SYSTEM CRITICAL DESIGN REVIEW - IMPLEMENTATION PLAN - which is expected to be available in the near future.