Appendix C
Other Incidents and Accidents

United Flight 585 at Colorado Springs

UAL Flight 585, a 737-200 ADV, crashed while on final approach to Colorado Springs, Colorado, on March 3, 1991. The aircraft was in its landing configuration, flaps 30 with the gear down, flying at 160 knots and just below 7,000 feet, when the accident sequence began. The aircraft appeared to be turning right onto the runway heading when it rolled sharply to the right until inverted, hitting the ground in a near-vertical dive.

Prior to and at the time of the crash of Flight 585, the weather conditions—including the wind speed and direction—were conducive to the formation of mountain waves and associated vortices and turbulence. There were numerous reports of severe weather from aircraft flying in the area and observers on the ground, including reports of unusually strong and shifting wind conditions near the time and place of the crash.[35]

During the initial investigation into the Flight 585 crash, the NTSB did not come to a definitive probable cause. The limited amount of data on the DFDR (only airspeed, altitude, heading, and load factor were recorded) made it difficult to determine the flight path of the aircraft, or the control inputs required to match the DFDR and radar data. The NTSB report on the accident[36] stated that the two events most likely to have resulted in a sudden uncontrollable lateral upset were a malfunction of the airplane's lateral or directional control system, or an encounter with an unusually severe atmospheric disturbance.

Studies of the Flight 585 accident were subsequently conducted at Boeing using techniques and tools developed during the Flight 427 investigation. These later studies have added to the information available concerning the Flight 585 accident.

Using the 737-200 ADV engineering simulator, it was possible to closely match the limited DFDR data using only the wheel and column as control inputs. The rudder was not used during the match except as commanded by the yaw damper, which was operational. The airspeed, altitude, normal load factor, and heading[37] from the simulation agree well with the DFDR data. In addition, the track of the airplane during the simulation matches the radar data recorded during the accident. The roll angle, pitch angle, and heading of the simulation at impact also agree with the data obtained at the accident site. The attitude of the aircraft during the accident sequence was also compared to results obtained in an NTSB study[38] conducted during the initial investigation, and was found to compare very well.

A match was also attempted using a simulated rudder hardover. For this scenario, it was possible to force a match of three of the four recorded DFDR parameters: airspeed, altitude, and heading. However, the load factor trace showed some significant discrepancies, and the track of the aircraft no longer matched the radar data from the accident. More significantly, the roll angle time history required to match the DFDR traces of airspeed, altitude, and heading no longer matched the witness reports of the Flight 585 accident.

Any introduction of rudder into the accident sequence requires a significant roll attitude change to maintain the DFDR heading. For the 5 deg/sec rudder input introduced in this case, the roll attitude had to be changed to more than 50 degrees to the left to maintain the heading recorded on the DFDR. This lateral orientation does not agree with what was observed by the many witnesses to the accident.

It should also be noted that, as demonstrated several times in flight testing conducted both by Boeing and the FAA, at flight conditions and flap settings similar to those existing at the onset of the Flight 585 accident, the rolling moment resulting from a rudder deflection to blowdown could easily be

[35] More details on the reported weather anomalies in the area of the accident can be found in the document *Boeing Contribution to the USAir Flight 427 Accident Investigation Board,* distributed to the NTSB Oct. 1996.
[36] *Aircraft Accident Report - United Airlines Flight 585 - Boeing 737-291, N999UA,* NTSB, Dec. 8, 1992.

[37] Heading agrees well up to the point where the single axis directional gyro is affected by the pitch and roll attitudes.
[38] *Flight Path Study,* NTSB Study, DCA 91-M-A023, Apr. 17, 1992.

countered using only about half the travel of the control wheel.

The new simulation match involving no rudder input can also be used to evaluate the possibility that a lateral control system failure caused the upset.

Since the Flight 585 match requires full right wheel to duplicate the upset, it follows that a portion of the system going hard over to the right could not cause the roll attitude required to obtain the match. This was demonstrated in the simulation using several hypothetical spoiler hardovers. In addition, the lateral control system is designed so that, in the event one element fails, the flight crew can override that failure and generally regain a controlling portion of the lateral control system.

The remaining potential cause of the Flight 585 accident identified in the NTSB report is a mountain rotor. Studies conducted by Boeing have determined that the simple rotor model used during the original investigation may not have been the most realistic model to use. Weather simulations based on the conditions present in the Colorado Springs area on the day of the accident have produced a different rotor model that has more realistic wind fields than those used during the earlier investigation, and that appears to cause a greater upset.

Figure 10 shows the match of the simulator to DFDR data given the rotor strength plotted as "P" shear. Also shown in the figure are the attitudes and wheel and rudder deflections consistent with the DFDR data. Work continues in this area, and simulations to date using the new rotor model appear to provide a reasonable match to the Flight 585 accident sequence.

The results of these studies have been shared with the NTSB staff, and additional work is being conducted in response to questions posed during NTSB review of these studies. The following summarizes the pertinent information obtained from simulator analysis of the Flight 585 accident:

1. The available DFDR data can be accurately matched with wheel and column control inputs only.
2. The introduction of rudder into the simulation causes the roll angle required to match the DFDR heading trace to deviate greatly from witness reports.
3. Only half wheel is required to control full rudder at the landing flap setting of Flight 585 at the onset of the upset.
4. Failure of the lateral control system could not have caused the upset since full lateral control to the right would be required.
5. A new model of a mountain rotor appears to provide a reasonable match to the Flight 585 accident sequence.

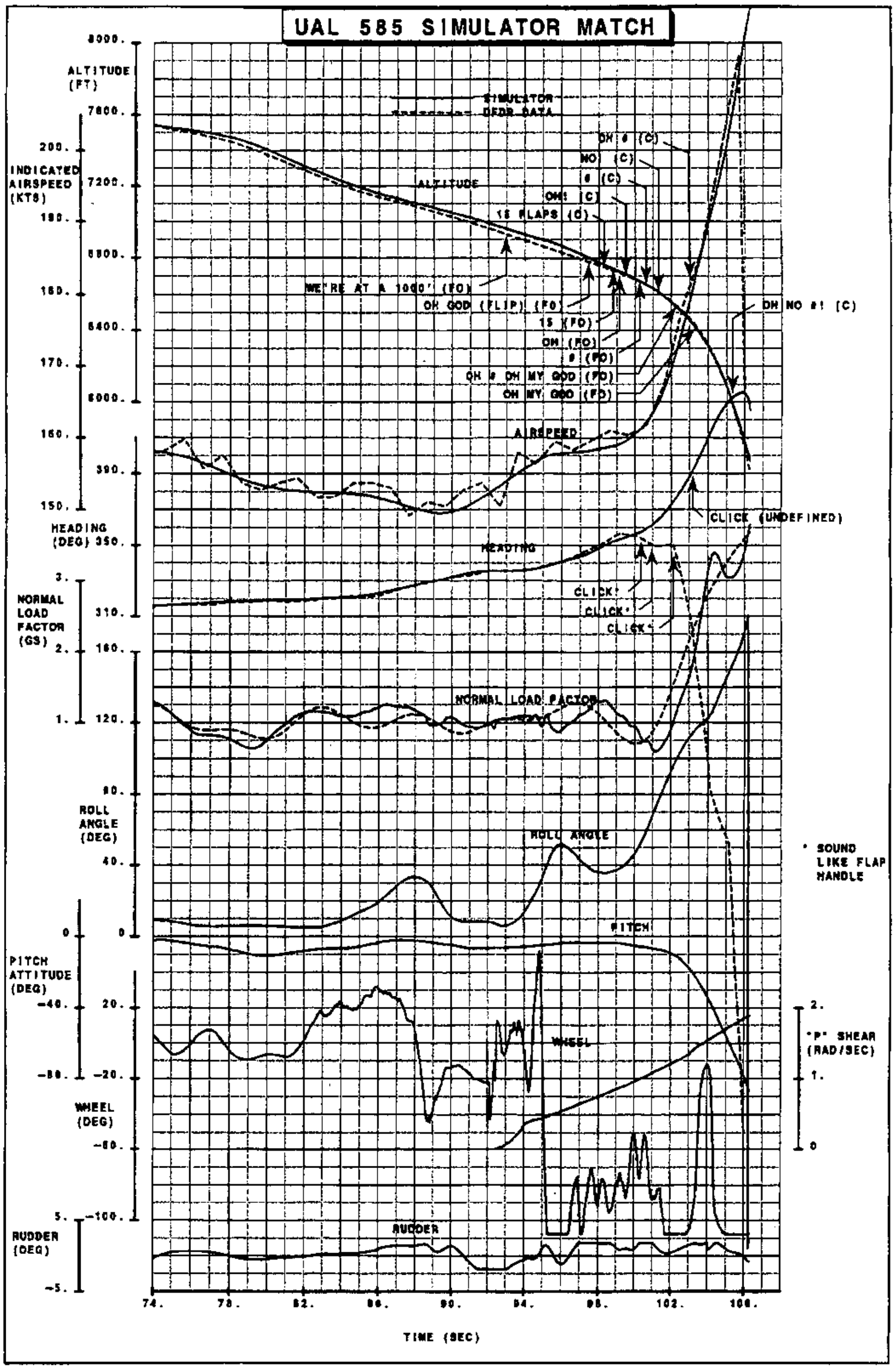

Figure 10: Flight 585 Simulator Match

Eastwind

The Eastwind aircraft was a 737-200 that experienced a yaw event to the right on the night of June 9, 1996, while on approach to Richmond, Virginia. The aircraft was not damaged during the event, and no one was injured. Instrumented flight testing of the aircraft after the incident did not produce any anomalous behavior, nor was there any evidence of a rudder jam observed in the post-accident examination.

This event is believed to have started with an electrical fault that caused a yaw damper hardover to the right. A kinematic analysis of this maneuver indicated that the initial rudder position reached during the yaw damper hardover was about four degrees.[39] This position is larger than the normal three-degree yaw damper limit, but is consistent with what a yaw damper hardover would produce, given that the damper position sensor on the Eastwind aircraft was found to have been misrigged.

It was also discovered that the incident aircraft's directional and vertical gyros produced errors, making estimations of rudder position difficult. Based on these somewhat questionable measurements, there was additional rudder movement in the same direction as the hardover. If this was the case, the rudder deflected to about six degrees, returned to near the yaw damper limit for that model 737, then returned to the greater deflection again, before finally returning to the expected yaw-damper-off position.

It is possible that the initial yaw damper hardover startled the crew. The event was more severe than a three-degree yaw damper hardover because of the misrigged position sensor. While the crew of the incident aircraft reported making left rudder inputs during the event, it is significant that the captain responded with wheel, throttle, and conceivably rudder inputs, all essentially at the same time. These near-simultaneous control responses were made at a time when the crew was encountering significant yaw and roll forces.

[39] The DFDR on this airplane recorded only 11 parameters and did not include any control parameters other than column.

The DFDR shows that the roll angle actually recovered back to wings level, and rolled in the opposite direction (to the left) during the recovery. Nevertheless, both crew members stated that the airplane was in a 25- to 30-degree bank to the right, when in fact the DFDR shows the airplane had rolled past wings level to the left.

Examination of the rudder PCU by the NTSB did not reveal any evidence of PCU malfunction, other than a misrigged yaw damper LVDT. Examination of the servo valve at NTSB offices in Washington, DC on March 12, 1997, did not reveal any evidence of a jam in the primary or secondary control valve slides.

The following summarizes the pertinent information obtained from analysis of the Eastwind incident:

1. The yaw damper position sensor was misrigged, causing a larger-than-normal rudder input due to the yaw damper hardover (i.e., 4.5° instead of 3°).
2. Bank and heading data from the incident was obtained from gyros that were producing erroneous data.
3. The crew responded to the upset with near-simultaneous inputs of wheel, throttle, and conceivably rudder. If additional rudder inputs were made, only two degrees of rudder input in the direction of the yaw damper hardover are required to match a derived rudder deflection.
4. The roll angle actually reversed from a right to a left bank during recovery, but both crew members perceived that the aircraft remained in a 25- to 30-degree right bank.
5. There is no evidence of any jam in the rudder servo valves.
6. The Flight 427 control valve testing demonstrated that the valve slides could not seize during any airplane operational scenario and also that it would not seize even for a thermal shock condition much more severe than what could ever be encountered by an in-service airplane. The Eastwind control valve slide clearances were greater than clearances for the Flight 427 control valve slides; therefore, neither the Flight 427 control valve nor the

Eastwind control valve could seize during any airplane operational scenario.

7. There is no evidence of a linkage jam in the rudder PCU, and a linkage jam does not match the kinematic analysis.

Sahara India

The Sahara India Airlines aircraft was a 737-200ADV that crashed during a training flight at Palam Airport near Delhi, India. The accident occurred following a touch-and-go landing at the airport. It was the instructor's first time as an instructor pilot, the training pilot's first time piloting a 737, and the airline's first attempt to do its own training.

The aircraft was equipped with a DFDR that recorded the following parameters of interest: roll angle, pitch angle, heading, normal load factor, longitudinal acceleration, column position, engine pressure ratio, airspeed, and altitude. The heading parameter is measured by a single-axis gyro that is subject to known errors when large bank and pitch angles are encountered.

The pilot in training was conducting a touch-and-go maneuver, which is commonly used during training to minimize flight time. Even though the instructor pilot had not briefed his trainee pilot that an engine-out exercise would be conducted, the instructor pilot apparently decided to introduce a simulated engine failure during the takeoff following the touch-and-go. As the aircraft rotated, the DFDR indicated that engine thrust was slowly reduced on the left engine. This reduction was halted momentarily after liftoff—while the instructor pilot retracted the landing gear after positive rate of climb was achieved—then continued until idle thrust levels were reached.

As thrust was reduced, the aircraft rolled left about 8 degrees and then returned to wings level. It then rolled sharply to the left to a maximum roll angle of 100 degrees. The bank angle was reduced to 60 degrees to the left before again rolling off to 80 degrees left at impact. Pitch angle was 20 degrees nose down at the time.

Figure 11 presents the results of a simulator study showing that wheel and some rudder were used to return the aircraft to wings level during the simulated engine failure. At about this time, the instructor pilot called out "rudder, rudder, rudder." The simulator evaluation showed that the rudder moved sharply to the left, which is the wrong direction to correct for a left engine failure. This caused the aircraft to roll rapidly to the left, even though the simulator evaluation showed that full right wheel was applied. The lateral control system was not able to overcome the roll due to sideslip, which was being generated by both the rudder and the thrust asymmetry.

As the maneuver progressed, the captain called out "leave, leave, leave," and the simulation indicates that the rudder input disappeared. This stopped the roll rate to the left, but it was too late to recover the aircraft from the large bank angle and nose-down pitch angle that had already developed.

The following summarizes pertinent information obtained from the simulator analysis:

1. The rudder was operational during the simulated engine failure.
2. The rudder was operational during the final seconds of the Sahara accident 3.
3. Wheel alone was not sufficient to reverse the rapid roll to the left; only the removal of the left rudder could have resulted in the bank angle time history recorded on the DFDR.

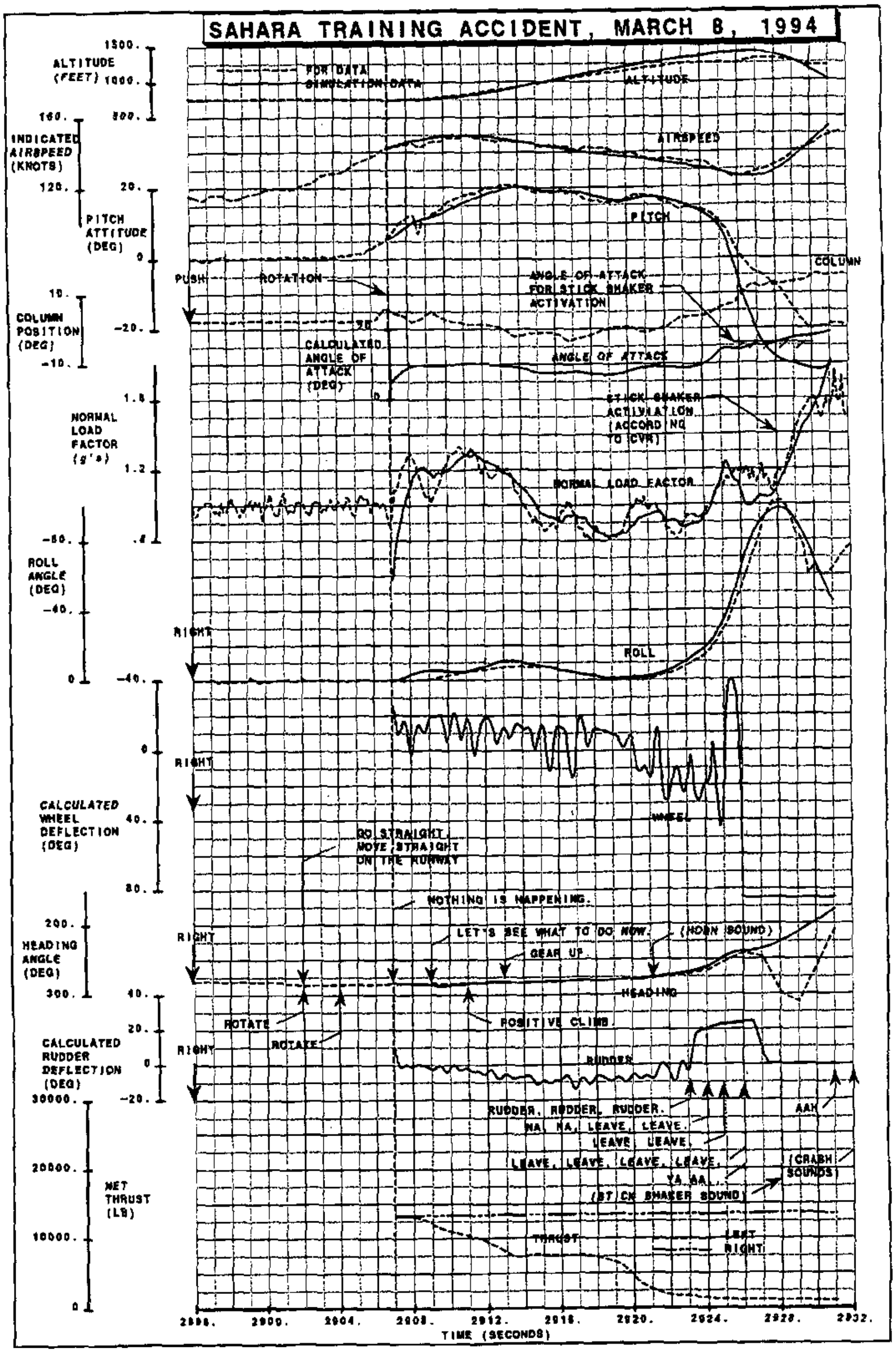

Figure 11: Sahara India Airlines Training Accident

Other "Uncommanded" Yaw and Roll Events

The analysis of 737 yaw and roll events that occurred between July 1995 and November 1996 are summarized in Table 5. Of the 78 events, a probable cause was identified for 53 events. Flight data were available for 59 of the total 78 events. The probable causes of the events are placed into four categories: system, crew, wake turbulence, and unexpected though normal aircraft response. The database from which Table 5 was constructed is shown in Table 6. All 737 roll/yaw events that were reported to the Aerodynamics Product Support group between July 1995, and November 1996 are listed. Those events which were the result of normal aircraft performance, yet were unexpected by the flight crew are listed as "normal" under the "cause" column.

The majority of events are roll events that are attributed to wake turbulence encounters. In each of the events caused by wake turbulence, perturbations in airspeed and/or normal load factor indicate that the event is due to a disturbance that is external to the aircraft systems. For many of the wake turbulence encounters, the flight data recorder data show wheel or aileron deflections in opposition to the roll. Also, for some of the events, analysis of the air traffic control radar data shows that the event aircraft location and the location of the wake turbulence from the preceding aircraft are coincident.

There were about twice as many roll events as there were yaw events which were attributed to system faults: 9 roll and 4 yaw events. More than one event was caused by faults in each of the autopilot (4) and yaw damper (3) systems. The autopilot faults resulted in disengagement of the autopilot and produced roll upsets smaller in magnitude than that demonstrated during certification of the autopilot system. During this certification, a fault was inserted into the autopilot which resulted in a lateral control deflection to the limit of the autopilot authority. The events attributed to yaw damper faults were the result of rudder deflections within the authority limit of the yaw damper. For each of the remaining system-caused events, a single event was attributed to each of the following: rudder trim switch fault, autothrottle asymmetry, landing gear oleo pressure asymmetry, manual reversion flight controls selection, spoiler actuator fault, and leading edge slat actuator fault.

The flight crew was the primary contributor to six events, all of which involved rolls. Two caused nacelle strikes during landing following control inputs made at touchdown. In another three events, the airplane responded properly to crew actions that involved FMC confusion, exceedance of the autopilot bank angle target, and roll due to fuel imbalance. In this last event, a roll-off at stall occurred when the flight crew apparently allowed the airplane to be stalled by the autopilot.

A probable cause was not determined for 27 of the 80 events. For 19 of these, no flight data were available for analysis.

<table>
<tr><th></th><th></th><th></th><th></th><th></th><th colspan="2">Unknown</th><th></th></tr>
<tr><th></th><th>System</th><th>Crew</th><th>Unexpected Airplane Response</th><th>Wake</th><th>With Data</th><th>Without Data</th><th>Totals</th></tr>
<tr><td>Roll</td><td>A/P Fault (4)
Gear Asymmetry
9 Manual Reversion
Autothrottle
Spoiler Actuator
L. E. Slat Actuator</td><td>6</td><td>2</td><td>30
1 (wind shear)</td><td>2</td><td>9</td><td>59</td></tr>
<tr><td>Yaw</td><td>4 Yaw Damper (3)
Trim Switch</td><td>0</td><td>1</td><td>0</td><td>5</td><td>11</td><td>21</td></tr>
<tr><td rowspan="2">Roll-Yaw Events Combined</td><td rowspan="2">16% (13)</td><td rowspan="2">8 (6)</td><td rowspan="2">4 (3)</td><td rowspan="2">39 (31)</td><td>9% (7)</td><td>25% (20)</td><td rowspan="2">80</td></tr>
<tr><td colspan="2">34 (27)</td></tr>
<tr><td>Roll-Yaw Excluding Unknown</td><td>25%</td><td>11%</td><td>6%</td><td>58%</td><td colspan="2">Total Unknown Events 27</td><td></td></tr>
</table>

Table 5: Uncommanded Yaw and Roll Event Summary

Airplane	Occurred	Event Description	Axis	Cause	FDR Data Avail.	FDR Data Received	Closed	Flight Phase
737-500	9/20/95	Exceedance of A/P Bank Limit	Roll	normal	Y	Y	5/24/96	Takeoff
737-500	4/13/96	Exceedance of A/P Bank Limit	Roll	normal	Y	Y	8/23/96	Takeoff
737-300	7/6/95	Wake Turbulence	Roll	wake	Y	Tab	9/27/96	Approach
737-300	7/18/95	Wake Turbulence	Roll	wake	Y	Y	1/17/96	Descent
737-300	8/5/95	Wake Turbulence	Roll	wake	Y	Y	1/17/96	Approach
737-300	8/25/95	Wake Turbulence	Roll	wake	Y	Y	1/17/96	Descent
737-300	8/30/95	Wake Turbulence	Roll	wake	Y	Y	1/17/96	Descent
737-500	9/6/95	Wake Turbulence	Roll	wake	Y	Y	1/15/96	Approach
737-300	9/29/95	Wake Turbulence	Roll	wake	Y	Y	1/17/96	Descent
737-300	9/30/95	Wake Turbulence	Roll	wake	Y	Y	1/17/96	Cruise
737-300	10/15/95	Wake Turbulence	Roll	wake	Y	Y	7/24/96	Approach
737-300	10/26/95	Wake Turbulence	Roll	wake	Y	Y	7/28/96	Approach
737-300	10/27/95	Wake Turbulence	Roll	wake	Y	Y	7/28/96	Approach
737-300	10/31/95	Wake Turbulence	Roll	wake	Y	Y	4/9/96	Descent
737-400	11/6/95	Wake Turbulence	Roll	wake	Y	Y	12/18/95	Approach
737-300	12/5/95	Wake Turbulence	Roll	wake	Y	Y	3/18/96	Final
737-400	1/18/96	Wake Turbulence	Roll	wake	Y	Y	3/29/96	Takeoff
737-200	2/9/96	Reported Wake Turbulence	Roll	wake	Y	N		Approach
737-500	2/15/96	Wake Turbulence	Roll	wake	Y	Tab	9/27/96	Descent
737-400	2/26/96	Reported Wake Turbulence	Roll	wake	Y	N		
737-300	4/1/96	Reported 777 Wake Turbulence	Roll	wake	Y	N		Approach
737-500	4/20/96	Reported 747 Wake Turbulence	Roll	wake	Y	N		Descent
737-400	5/8/96	Reported Wake Turbulence	Roll	wake	Y	N		Descent
737-300	6/29/96	Wake Turbulence	Roll	wake	Y	Y		Descent
737-500	7/24/96	Wake Turbulence	Roll	wake	Y	Y	9/27/96	Descent
737-200	8/12/96	Reported 747 Wake Turbulence	Roll	wake	N			Approach
737-300	8/13/96	Wake Turbulence	Roll	wake	Y	Y	9/12/96	Approach
737-400	8/18/96	Wake Turbulence	Roll	wake	Y	Y	9/30/96	Approach

Table 6: Aerodynamics Product Support – 737 Roll/Yaw Events

Airplane	Occurred	Event Description	Axis	Cause	FDR Data Avail.	FDR Data Received	Closed	Flight Phase
737-500	9/5/96	Wake Turbulence	Roll	wake	Y	Y	9/27/96	Descent
737-500	9/6/96	Wake Turbulence	Roll	wake	Y	Y	9/27/96	Descent
737-300	10/13/96	Wake Turbulence	Roll	wake	Y	11/14/96	3/3/97	Descent
737-200	11/8/96	Wake Turbulence	Roll	wake	Y	Y	1/3/97	Approach
737-300	3/15/96	Windshear	Roll	weather	Y	Tab		Approach
737-400	7/16/95	Reported A/P Induced Roll	Roll	system	N			Climb
737-300	7/25/95	Unexpected A/P Disconnect	Roll	system	Y	Y	1/17/96	Approach
737-400	8/11/95	Gear Strut Asymmetry	Roll	system	Y	Y	7/9/97	Takeoff
737-200	9/25/95	Reported Uncommanded Roll A/P Eng/Diseng.	Roll	system	N			
737-300	10/22/95	Uncommanded Roll at A/P Engage	Roll	system	Y	Y	4/10/96	Approach
737-300	4/28/96	Reported Uncommanded Roll w Asymmetric A/T	Roll	system	Y	N		Descent
737-200	8/18/96	Reported Roll at Manual Reversion Check	Roll	system	N			Cruise
737-200	11/2/96	#3 L.E. Slat Failed	Roll	system	N			Climb
737-200	11/29/96	Reported Uncommanded Roll w/ Spoiler Actuator Fault	Roll	system	N			Approach
737-400	7/25/95	Crew/FMC Confusion	Roll	crew	Y	Y	1/17/96	Approach
737-500	10/2/95	Nacelle Strike	Roll	crew	Y	Y	2/26/96	Landing
737-500	11/10/95	A/P Bank Angle Exceedance	Roll	crew	Y	Y	5/24/96	Takeoff
737-400	7/28/96	Wingtip Strike and Hard Landing	Roll	crew	Y	Y	1/13/97	Landing
737-400	9/18/96	Fuel Imbalance, Roll at A/P disconnect	Roll	crew	Y	N		Climb
737-200	11/14/96	Apparent Flaps Up Stall	Roll/Pitch	crew	Y	Y		Test
737-300	11/10/95	Uncommanded Roll	Roll	unknown	N			Approach
737-200	1/2/96	Uncommanded Lateral Oscillation	Roll	unknown	N			Climb
737-200	1/14/96	Uncommanded Roll	Roll	unknown	Y	Y	9/27/96	Approach
737-300	7/14/96	Wingtip Strike and Hard Landing	Roll	unknown	N			Landing
737	7/24/96	Nacelle Strike	Roll	unknown	N			
737	7/24/96	Nacelle Strike	Roll	unknown	N			
737-300	7/25/96	Uncommanded Roll at Flare	Roll	unknown	Y	Y		Landing
737-200	8/8/96	Hard Landing, Nacelle Strike	Roll	unknown	N			Landing
737-500	8/23/96	Roll Exceedance	Roll	unknown	N			Climb

Airplane	Occurred	Event Description	Axis	Cause	FDR Data Avail.	FDR Data Received	Closed	Flight Phase
737-400	10/16/96	Reported Yaw/Roll Motion	Roll/Yaw	unknown	N			Climb
737-200	UKN	Uncommanded Roll	Roll	unknown	N			Cruise
737-300	7/10/96	Uncommanded Yaw	Yaw	normal	Y	Y	1/8/97	Takeoff
737-300	7/25/95	Reported Y/D Hardover	Yaw	system	Y	Y	4/9/96	Approach
737-300	9/29/95	Rudder Trim Runaway	Yaw	system	Y	Y	2/20/97	Climb
737-200	10/22/95	Sustained Dutch Roll, Y/D Fault	Yaw/Roll	system	Y	Y	11/28/95	Cruise
737-200	7/25/96	Uncommmanded Yaw	Yaw	system	Y	Y	9/27/96	Takeoff
737-200	7/24/95	Reported Uncommanded Rudder	Yaw	unknown	N			Climb
737-200	8/1/95	Uncommanded Yaw w/ Loud Thud	Yaw	unknown	Y	N		
737-400	8/18/95	Reported Yaw just Prior to T/D	Yaw	unknown	Y	N		Approach
737-200	8/21/95	Reported Yaw Anomaly at Takeoff	Yaw	unknown	Y	Tab		Takeoff
737-200	9/10/95	Reported Yaw Prior Takeoff Rotation	Yaw	unknown	Y	N		Takeoff
737-300	3/6/96	Uncommanded Yaw	Yaw	unknown	N			
737-200	4/21/96	Runway Excursion w/ A & B Hyd Loss	Yaw	unknown	N			Landing
737-200	5/14/96	Uncommanded Yaw w/o Pedal Deflect.	Yaw	unknown	Y	Y		Climb
737-200	6/1/96	Uncommanded Yaw	Yaw	unknown	Y	Y		Descent
737-200	6/8/96	Uncommanded Yaw w Y/D Disengaged	Yaw	unknown	Y	N		Unknown
737-200	6/9/96	Uncommanded Yaw w/ Stiff Pedal Feel	Yaw	unknown	Y	Y		Descent
737-300	8/2/96	Runway Excursion, Heavy Rain	Yaw	unknown	N			Landing
737-500	8/3/96	Uncommanded Yaw w/ Pedal Motion	Yaw	unknown	N			Takeoff
737-400	8/3/96	Runway Excursion, Rain & Wind	Yaw	unknown	N			Landing
737-500	8/15/96	Uncommanded Yaw	Yaw	unknown	N			Approach
737-300	11/16/96	Uncommanded Yaw	Yaw	unknown	Y	Y		Takeoff

Table 6: Aerodynamics Product Support – 737 Roll/Yaw Events

The following conclusions and recommended actions were extracted from the *737 Roll Team Report* dated January 18, 1996.

6. Conclusions and Recommended Actions:
6.3 Specific Event-Related Actions

The team was unable to find a single system fault mode that would explain the high rate roll upsets for flaps-up operation. The combined system fault modes investigated were capable of generating the higher roll rates, but the load factor and airspeed perturbations, evident in many of the roll upset events, are absent from the system failure responses.

There were several in-service events that were isolated to specific system failures or to crew interface issues. The hardware failure cases (autopilot disconnect, rudder trim switch fault, gear strut charging, and the failed aileron actuator) are unrelated. The rudder trim switch fault represents a "dual" fault state since the single failure bypassed both the "arm" and "command" features of the trim control. It is recommended that component Service Bulletin 69-73703-27-02 dated 9/24/92 be incorporated by all operators to take advantage of the improved trim switch design.

All of the studied events produced upsets that were controllable by the flight crew.

Three crew interface events were examined. In the first event, the crew misunderstood the interaction between autopilot Heading Select and FMC L-NAV path control. The second relates to a report of an unexpected roll whereas the FDR data appears to reflect normal Heading Select operation. The third condition resulted from inadvertent activation of the lateral trim system while the autopilot was engaged. This resulted in a roll upset upon autopilot disengagement. The first and last events appear to be crew awareness issues and may relate to crew training. The second is a puzzle. There appears to have been some crew interaction with the MCP since the Bank Angle limits are different for two Heading Select changes that occurred in little over a minute. No recommendation is made for these crew issues.

The remaining events, where the team was able to identify a possible root cause, indicated wake turbulence encounters. These short-duration events have high roll rates and caused crew concerns on several occasions. The recovery techniques vary between flight crews with some crews using rudder inputs as part of the recovery technique. The upsets for wake encounters need to be reviewed by the Boeing crew training organization to determine if special crew training, alternate means of informing the crew is required, and/or to determine if recommended recovery techniques need to be established.

This completes the team conclusions and recommendations.