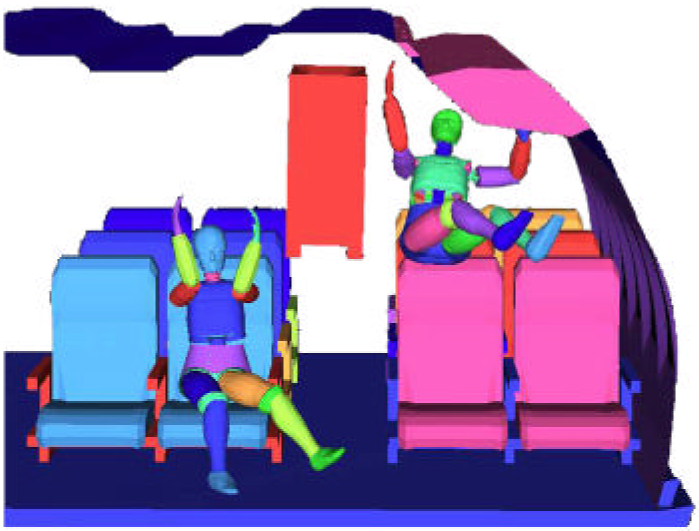
TURBULENCE JOINT SAFETY ANALYSIS TEAM (JSAT)



Analysis and Results

January 12, 2001

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1.0 EXECUTIVE SUMMARY

1.1 Define The Problem

Although turbulence does not produce a high number of commercial aviation fatalities when compared to other categories of accidents addressed by the Commercial Aviation Safety Team (CAST), turbulence has produced more serious injuries to passengers than any other class of accident. Similarly, the frequency of turbulence accidents in the past several years has created a somewhat disproportionate level of public concern. Accordingly, the CAST chartered the Joint Safety Analysis Team (JSAT) to review and analyze data on turbulence-related accidents and incidents, including wake turbulence, and to recommend interventions that will reduce the frequency of turbulence accidents and injuries in commercial aviation.

In the CAST process, government and industry have agreed to work together to identify and implement a data driven, benefit focused, safety enhancement program designed to continuously improve the safe commercial aviation system of the United States. The CAST has further agreed that cooperatively and selectively pursuing the critical few high leveraged safety intervention strategies will maximize the safety benefit to the flying public through a focused application of industry and government resources. To that end, the JSAT seeks to use the CAST process to ultimately reduce the potential for turbulence encounters to reduce injuries by 80% by the year 2007 and to reduce the potential for both passenger and flight attendant injuries when turbulence encounters are unavoidable. This report summarizes the analyses and results of the JSAT.

The JSAT Charter (Appendix A) identifies three major tasks:

> 1-The team shall acquire available data, including prior studies and analyses. The data will be used to conduct a causal analysis to determine the proximate cause of fatalities and injuries during operations under 14 CFR 121.
>
> 2-The team shall use the process defined in the JSAT Process Document to identify, document, and evaluate the effectiveness of potential weather and turbulence intervention strategies, that are designed to prevent turbulence related injuries.
>
> 3-The process shall include a technical review as defined by the JSAT Process Document. Results of the technical review will be presented to the JSAT for consideration prior to final report submittal to CAST.

A review of the literature and supporting data used by the JSAT indicates that the United States (US) air carrier system is exposed to a high frequency of turbulence encounters resulting in injuries. This exposure is due to several factors, including the convergence of jet streams over North America, mountain wave and associated activity over the Rocky Mountains, high incidence of convective activity over North America, and the influence of the Caribbean and the Gulf Stream in the Southern and mid-Atlantic Regions as well as operating globally in remote areas where forecasting is significantly less reliable. There is also a high exposure risk along the western rim of the Pacific Ocean, where US carriers provide Asian services. In contrast, Western Europe tends to be a region of low turbulence frequency and exposure there is low.

Turbulence data from 1980 to 1999 shows an average of six or seven accidents and eight serious injuries per year through 1995. The average then rises suddenly and peaks in the late 1990's at 12 accidents and 16 serious injuries per year. This trend, coupled with the increase of commercial travel predicted for at least the next decade, projects a higher risk level for serious injury or fatality of passengers and cabin crewmembers.

During the 16-year period ending in 1999, US air carriers experienced 131 turbulence-related accidents, with a total of three passenger fatalities (one each in 1987, 1990 and 1997). In addition to the three fatalities, 83 passengers and 93 flight attendants suffered serious injuries, while 423 passengers and 121 flight attendants suffered minor injuries.

Passengers accounted for almost 94 percent of persons onboard the 131 accident aircraft, but they accounted for only 48 percent of the fatal and serious injuries, and close to 78 percent of minor injuries. In contrast, flight attendants accounted for just over 4 percent of people onboard but 52 percent of serious or fatal injuries, and slightly over 22 percent of minor injuries. The risk per flight attendant of serious injury in turbulence was nearly 24 times higher than the risk per passenger. The flight attendant risk of minor injury was more than six times higher than the risk for passengers. It is apparent that a major factor in the higher risk for flight attendants is due to the requirement that flight attendants to be unrestrained while performing a majority of their crew duties.

Injuries to flight attendants are of even greater concern than those to passengers. This is true not only because of the high number of flight attendants injuries but because the flight attendant's primary role is cabin safety and an injured flight attendant may not be able to perform evacuation and other potentially critical functions. Data from the FAA Accident and Incident Data System and from one of the major US air carriers, indicates that injuries to flight attendants have a major effect on operating costs and worker injury time. FAA incident data indicates that, for every turbulence accident with serious injuries, three significant incidents without serious injuries are reported to the agency. Data provided by one airline indicates that, for every flight attendant seriously injured in a turbulence accident, 70 flight attendants receive National Transportation Safety Board (NTSB) defined minor injuries in turbulence incidents, causing an average of more than 11 workdays lost per reported injury. Assuming that the ratios for this large carrier are roughly representative of the entire industry through 1994, an average of 10,000 flight attendant work days have been lost throughout the industry each year in each of the past 16 years. In the five years from 1995 to 1999, that average has dramatically increased to nearly 15,000 lost workdays per year throughout the industry.

1.2 The JSAT Process

The JSAT process is disciplined and is both data driven and consensus based. The process, which progresses from data selection and analysis, through problem statement and intervention identification, culminates in a prioritized intervention strategy for use by the follow-on efforts of the Joint Safety Implementation Team (JSIT). The Turbulence JSAT endeavored to remain faithful to the JSAT process while confronting issues unique to the analysis and evaluation of turbulence incidents and interventions and on several occasions sought advice from CAST process monitors to ensure compliance with the JSAT process.

The establishment and structure of the JSAT was typical of the CAST process, as was the composition of the team. An organizational review of the team may be found in paragraph 3.1.1. After reviewing the initial sets of data available, a selection of 149 accidents and 40 incidents was chosen. Three sub-teams were formed, and the data set was divided based on year of occurrence. The standard CAST list of accident characteristics and indicators was supplemented, particularly in the areas of meteorological information, cabin crew activity, and air traffic control. Event sequences were developed by the sub-team members to identify the series of events leading up to the accident/incident. Next, sub-teams formulated problem statements to describe situations in the event sequence that caused increased risk of turbulence injuries or where deficiencies were noted. Deficiencies included failure to follow procedures, equipment failures, maintenance failures, inappropriate crew responses, and other similar problems. Contributing factors were also written at this stage, to help clarify the problem statements and explain why the problem occurred. Contributing factors helped focus on developing standard problem statements (SPS) and intervention strategies.

A total of 21 problem statements were finally selected, nine of which had come from other JSATs. These problem statements were arranged in groupings, which were: 1-Flight Crew; 2) Cabin Crew; 3) Air Traffic Control; 4) Aircraft Equipment; 5) Passenger; 6) Airline Operations; 7) Weather Information/Weather Providers; and 8) Type of Turbulence. A list of the standard problem statements and definitions may be found in Appendix E. A matrix was developed for distribution of the problem statements across the data set, and may be seen in Appendix F. Additionally, a matrix was developed to show the distribution of injuries and fatalities across the data set, and that data may be seen in Appendix G.

Each problem statement generated one or more interventions, and the intervention strategies of the three sub groups were collated into a single set of interventions with broader applications. A total of 39 intervention strategies emerged and were applied to the standard problem statements to check for applicability. Some accident/incident cases were removed from the process at this point when it was determined a lack of data existed for a clear understanding of the event. The final stages of the JSAT process were applied to the remaining 51 cases. These intervention strategies appear in Appendix H. A matrix was developed to show the distribution of intervention summaries across the data set, and that summary is shown in Appendix I.

Each of the three sub-teams rated its assigned cases according to their Power, Confidence and Applicability (PCA). Power is defined as how well the intervention directly and definitely addresses the problems/contributing factors in the accident, and by doing so, would have reduced the likelihood of the accident, if everyone/everything performed as the intervention intended. Confidence deals with how strongly we believe that everyone/everything will perform as expected. The Confidence factor brings in an assessment of the real world, where interventions do not always have the desired effect. Applicability relates to how frequently the problem(s) being addressed by the intervention will continue to be present on a widespread basis in future operations, nominally, circa 2007. At the conclusion of this round, every intervention had a PCA rating each time it appeared in each case. As a result, most interventions had multiple PCA ratings; that is, an intervention was applied more than once in a case. All intervention strategies with multiple PCA ratings within a case were reviewed to consolidate one PCA rating per intervention per case. Consensus was achieved for each intervention rating within a case.

The final step in evaluating intervention effectiveness was to consolidate the PCA scores for a specific intervention across all cases into one PCA score, arriving at a single PCA score for each of the interventions. Eventually, a refinement of the interventions brought a consolidation from 39 interventions to 30. The 30 interventions were then accepted by the JSAT plenary and team members reached consensus on the single PCA rating for each intervention. This resulted in one PCA rating for each of the 30 interventions. The interventions were then prioritized in accordance with the CAST method for determining overall effectiveness.

An important key to understanding the eventual recommendations put forth by this JSAT is a clear interpretation of the Turbulence Avoidance and Mitigation Flow Chart (Figure 5) that is used as a tool to capture and organize information gleaned from the accidents and incidents, and reveal useful patterns. No-risk, low-risk, and high-risk scenarios are individually demonstrated on separate versions of the chart (Figures 6a, 6b, 6c). In the no-risk scenario, the aircraft completely avoids turbulence. Two paths are possible, either one of which allows successful turbulence avoidance. In the low-risk scenario, penetration of turbulence ensues only if any of the possible steps in the flow prompt a negative reply. The high-risk scenario comes as a result of no warning of ensuing turbulence or unprepared turbulence penetration. Without that warning, any of the possible danger links on the flow chart could be connected and a turbulence encounter will occur.

1.3 Identifying Interventions

1.3.1 Avoid Turbulence Encounters.

After evaluating individual intervention effectiveness utilizing the flow charts, interventions were grouped by type and task. Clearly the optimum overall solution to preclude turbulence injuries and fatalities is to avoid turbulence altogether. There are three fundamental intervention sets needed to avoid turbulence. Those steps are: (1) to improve turbulence information available to decision makers in pre-flight and in-flight stages, (2) to improve preflight/in-flight decision making for turbulence avoidance, and (3) to improve route selection options, especially in the oceanic regime.

1.3.1.1 Improve Weather Information for Pre-Flight and In-Flight Turbulence Avoidance Decisions.

Improving weather information for pre-flight and in-flight turbulence avoidance decisions entails implementation of several steps. Airlines must either develop or subscribe to a comprehensive meteorological program that provides turbulence charting and alerting. The quantity and timeliness of pilot reports (PIREPS) available to pilots, dispatchers and forecasters must be improved to pinpoint location and severity of turbulence. In-flight turbulence detection capabilities are needed; turbulence forecasting must improve; and the overall utility of turbulence products for decision makers must improve.

1.3.1.2 Improve Pre-Flight and In-Flight Decision Making for Turbulence Avoidance.

Even when accurate, advance information on turbulence location and intensity is available; there are significant failures on the part of decision-makers to properly use that information in the avoidance of turbulence. A number of specific interventions drawn from the turbulence cases studied would address this need. Government and industry should develop and implement better guidance for buffer zones around thunderstorms, the sources of many turbulence encounters. Airlines should provide adequate initial and recurrent training to flight crews on the fundamental understanding of the assessment, recognition and avoidance of turbulence. Government and industry should employ and jointly train for Collaborative Decision Making (CDM) for improved turbulence forecasts. Airlines need to insure that they acquire and make better use of currently available products, including Significant Meteorological Information (SIGMETs), Pilot Reports (PIREPs), Airmen's Meteorological Information (AIRMETs), and other services including Flight Watch and the Hazardous In-flight Weather Advisory Service (HIWAS).

1.3.1.3 Improve Pre-Flight and In-Flight Oceanic Route Selection Options.

Because of the inflexibility of oceanic route changes once en route traffic leaves positive radar coverage, Air Traffic Control should allow greater flexibility in oceanic route and altitude selection (including altitude selection) to enable better turbulence avoidance in the oceanic environment.

1.3.2 Mitigate the Impact of Turbulence on Aircraft Occupants.

Often turbulence can not be avoided, either because the information about its location and intensity is not available or adequate, or there are no completely turbulence-free routes. In these cases, active or passive measures to mitigate the impact of turbulence are the best tools to lower injury and fatality rates. These measures are generally classified into (1) reduction of passenger exposure through better compliance with seating and seat belt directions, (2) reduction of flight attendant exposure through policies and procedures requiring that they be seated and restrained during periods of high exposure, (3) reduction of both passenger and cabin crew exposure through improved interior aircraft design, and (4) redesign of aircraft flight controls to dampen the effects of turbulence.

1.4 Recommended Intervention Sets

So far, the JSAT has presented the interventions in relationship to groupings of the standard problems they are intended to resolve. Some sets of interventions share common purposes and had similar Operational Effectiveness scores (OEs). The JSAT recommends four such sets in which OEs are relatively high, for priority consideration by the JSIT. An intervention qualifies as relatively high if its OE is above 2.1, which is the mean OE for all interventions.

Note that the other interventions not clustered under these four recommendations are considered viable on their own merits. They should be carefully considered by the JSIT as well.

Recommendation 1: Improve The Use Of Available Information

The Turbulence JSAT found that the best way to reduce turbulence injuries is for airlines to implement a focused program of avoiding turbulence in the first place and the best way to avoid turbulence encounters is through better use of currently available information about turbulence. Accordingly, the set of interventions addressed improved acquisition, display, synthesis, and sharing of current information as well as those that would yield better interpretation and understanding of currently available information scored highest as a group.

Recommendation 2: Improve Information About The Location And Severity Of Turbulence.

The JSAT also highly rated and identified a set of interventions that had the potential to help avoid turbulence altogether, including airborne sensors, passive on-board acceleration sensors/transmitters, better forecast accuracy, more PIREPS, better detection of low reflectivity thunderstorms, and a fully formal Collaborative Convective Forecast Product (CCFP).

Recommendation 3: Improve Risk Management For Flight Attendants

The JSAT found that flight attendants experienced the highest injury rate of all of those exposed to turbulence. Consequently a set of interventions aimed to reduce injuries among flight attendants was selected to, collectively, provide better risk management for flight attendants in the performance of their duties, including policy to: 1) remain seated from takeoff to cruise and from FL 200 to landing; 2) prioritize seat belt monitoring duties and cabin service, to place a higher priority on their own safety, and; 3) provide better training so that flight attendants better understand turbulence and the risks to which they are exposed during turbulence.

Recommendation 4: Improve Communications
The final set of interventions that had a high potential to reduce turbulence injuries has a common theme of communications. Improvement in on-board communications between the flight deck and the cabin crew, between the flight deck and passengers, and between the flight attendants and passengers all have potential to reduce turbulence injuries.

2.0 BACKGROUND AND INTRODUCTION

2.1 Background

Though turbulence does not produce a high number of commercial aviation fatalities when compared to other categories of accidents addressed by the CAST, turbulence has produced more serious injuries to passengers than any other class of accident. Similarly, the frequency of turbulence accidents in the past several years has created a somewhat disproportionate level of public concern. Accordingly, the CAST chartered the Joint Safety Analysis Team (JSAT) to review and analyze data on turbulence-related accidents and incidents, including wake turbulence, and to recommend interventions that will reduce the frequency of turbulence accidents and injuries in commercial aviation.

2.2 Description of the Problem

A review of the literature and supporting data (see Appendix M) indicates that the US air carrier system is exposed to a high frequency of turbulent encounters resulting in injuries. This is due to several factors, including the convergence of jet streams over North America mountain wave and associated activity over the Rocky Mountains, high incidence of convective activity over North America, and the influence of the Caribbean and the Gulf Stream in the Southern and mid-Atlantic Regions. Another region of concentrated turbulence is along the western rim of the Pacific Ocean. In contrast, Western Europe tends to be a region of low turbulence frequency.

2.2.1 General Trends

From 1980 through 1999, the number of fatal and serious injuries to passengers and flight attendants incurred during those accidents. Despite some annual variation, the figures show that the average number of accidents and injuries remained fairly stable from 1980 through 1994, at about six or seven accidents and about eight injuries per year, including one fatal injury in 1987. Since aircraft operations increased during that period, the rate at which turbulence accidents occurred decreased in those years. However, from 1994 through 1999, the average increase to 12 accidents and 16 injuries per year, including one fatal injury in 1990 and 1 in 1997. Without meaningful intervention, this trend may continue to rise because, coupled with overall increases of commercial travel, higher levels of risk for serious or fatal injury are generated for passengers and cabin crew members.

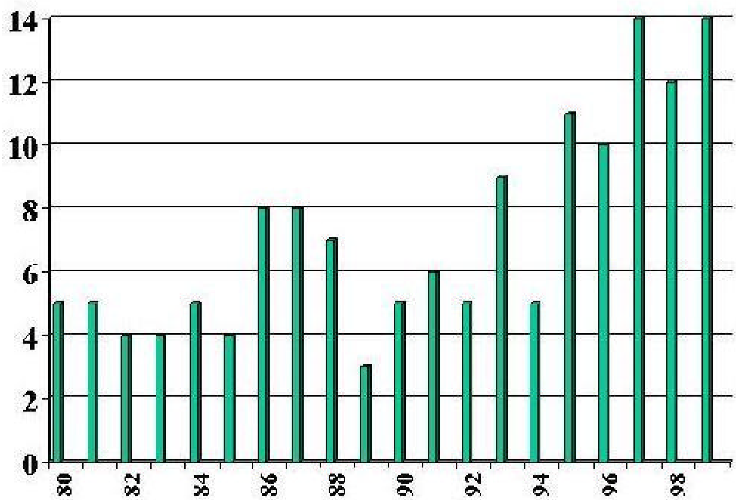

Figure 1: Number of Turbulence Accidents, US Air Carriers, 1980-1999
Source: NTSB Accident Data, compiled by Dr. Robert Matthews, Ph.D., Federal Aviation Administration, Office of Accident Investigations

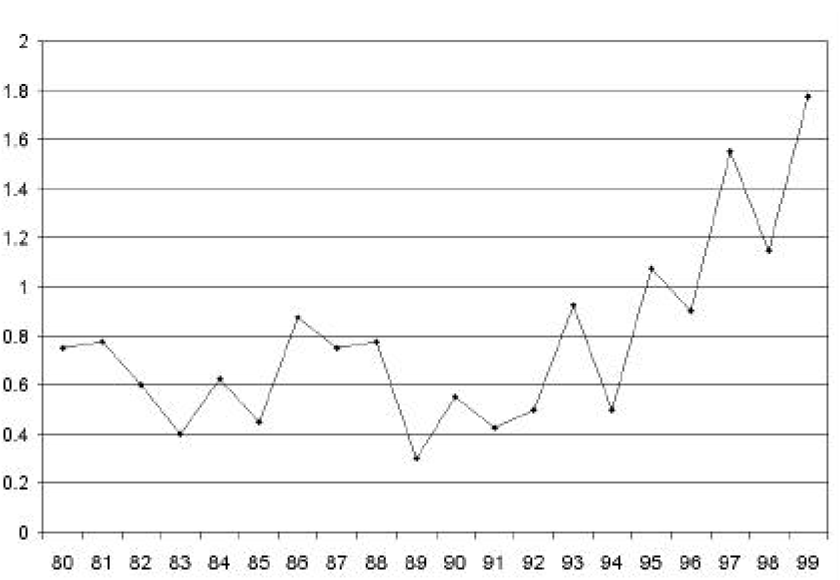

Figure 2: Turbulence Accidents per Million Flights, US Carriers, Based on 14 CFR 119 Definition
Source: NTSB Accident Data, compiled by Dr. Robert Matthews, Ph.D., Federal Aviation Administration, Office of Accident Investigations

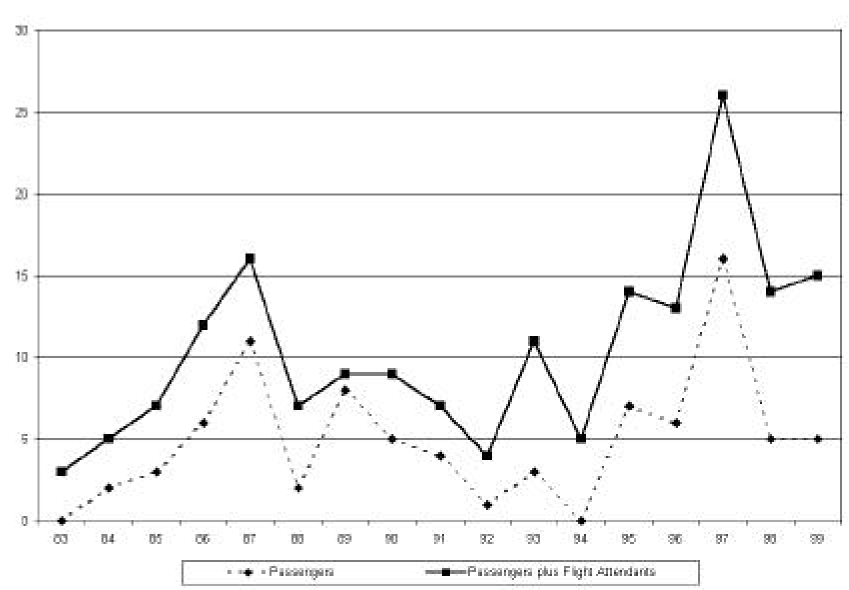

Figure 3: Serious Injuries to Passengers and Flight Attendants in Turbulence Accidents, 1983-1999 (Includes three fatal passenger injuries)
Source: NTSB Accident Data, compiled by Dr. Robert Matthews, Ph.D., Federal Aviation Administration, Office of Accident Investigations

2.2.2 Accident Characteristics

From 1983 through 1999, US air carriers had 131 turbulence and wake turbulence accidents, with a total of three fatal injuries to passengers (one each in 1987, 1990 and 1997). Figure 4 summarizes the turbulence accidents and injuries for the US carriers from 1983 through 1999. In addition to the three fatal accidents, 83 passengers and 93 flight attendants received serious injuries, while 423 passengers and 121 flight attendants received minor injuries.

In 1997, the definition of 14 CFR 121 was changed to include what had been 14CFR 135 aircraft. Appropriate shares of what had been 14 CFR 135 accidents and departures have been included in Figure 4 to normalize the rates.

	# of Accidents	Passenger Fatal	Passenger Serious	Passenger Minor	# Passengers On Board	Flight Attendant Serious	Flight Attendant Minor	# Flight Attendant On Bd	Pilots On Board	TOTAL Fatalities	TOTAL Serious Injuries	TOTAL Minor Injuries	TOTAL On Board
1983	4	0		6	276	3	1	13	10	0	5	7	299
1984	5	0	2	5	498	3	5	29	13	0	5	10	540
1985	4	0	3	19	228	4	2	18	9	0	7	21	255
1986	8	0	6	29	986	6	18	47	18	0	12	47	1051
1987	8	1	10	68	882	5	9	39	20	1	15	77	941
1988	7	0	2	8	957	5	11	46	15	0	7	19	1018
1989	3	0	8	21	368	1	2	21	8	0	9	23	397
1990	5	1	4	61	532	4	8	24	11	1	8	69	567
1991	6	0	4	21	648	3	4	32	12	0	7	25	692
1992	5	0	1	0	520	3	1	23	12	0	4	1	555
1993	9	0	3	18	932	8	8	48	18	0	11	26	998
1994	5	0	0	0	860	5	3	33	11	0	5	3	904
1995	11	0	7	10	1371	7	1	68	23	0	14	11	1462
1996	10	0	6	27	1030	7	3	34	20	0	13	30	1084
1997	14	1	15	21	2135	10	17	101	30	1	25	38	2266
1998	12	0	5	22	1517	9	8	68	26	0	14	30	1611
1999	15	0	5	87	1637	10	20	74	25	0	15	107	1742
	131	3	83	423	15377	93	121	718	287	3	176	544	16382

Figure 4: Turbulence Accidents and Injuries, US Air Carriers, 1983-1999
Source: NTSB Accident/Incident Data

Passengers accounted for almost 94 percent of persons onboard the 131 accident aircraft, but they accounted for only 48 percent of the fatal and serious injuries, and close to 78 percent of minor injuries. In contrast, flight attendants accounted for just over four percent of people onboard but 52 percent of serious or fatal injuries and over 22 percent of minor injuries. The incidence of serious injury in turbulence was nearly 24 times higher per flight attendant than the risk per passenger, while the risk of minor injury was more than six times higher.

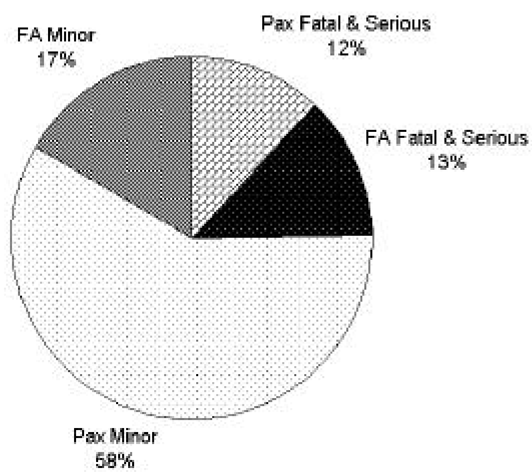

Figure 5: Breakdown of Total Passenger and Flight Attendant Injuries

Injuries to flight attendants, as with passengers, are a significant concern. Data from FAA's Accident and Incident Data System and from one of the major U.S. air carriers indicates that injuries to flight attendants have a major effect on operating costs and worker injury time. FAA incident data indicates that, for every turbulence accident with serious injuries, three significant incidents without serious injuries are reported to the agency. Data from a large air carrier indicates that, for every flight attendant injured in a turbulence accident, 70 flight attendants receive presumably minor injuries (as defined by NTSB) in turbulence incidents. These injuries, including those recorded by NTSB in accidents, cause an average of 11.4 workdays lost per reported injury. Assuming that the ratios for this large carrier are roughly representative of the entire industry, an average of 10,000 flight attendant work days have been lost throughout the industry each year since 1983. In the past 5 years (1995-1999), that average has dramatically increased to nearly 15,000 lost workdays throughout the industry.

2.3 Past Turbulence Efforts

Two workshops focused on aircraft turbulence accident prevention have been conducted in the past four years. The first was held in Boulder, CO in February 1997 and was hosted by the National Center for Atmospheric Research (NCAR). The second was held in Hampton, VA in August 1998 and was co-hosted by the NASA Aviation Safety Program Office, Langley Research Center and the Aviation Weather Directorate, Federal Aviation Administration.

A bibliographical search was conducted without success to identify any broadly scoped past efforts to reduce turbulence-related injuries. Several documents were found that documented turbulence accident statistics over several time windows beginning in 1972. Other references were written to address specific problem areas (such as decision-making, communication, or cabin procedures). However, no comprehensive effort was discovered that has addressed the full range of issues except from this JSAT activity. References are included in the bibliography found in Appendix M.

2.4 JSAT Charter And Scope

The Turbulence JSAT was chartered to review and analyze atmospheric enroute turbulence related aviation accidents and incidents for the purpose of developing and recommending implementation strategies that could reduce the potential for injuries and fatalities. A copy of the Turbulence JSAT charter is provided as Appendix A.

3.0 THE ANALYSIS PROCESS

The JSAT process is disciplined, data driven and consensus based. The process, which begins with data selection and analysis progresses to problem statement and intervention identification and culminates in a prioritized intervention strategy for use by the follow-on efforts of the Joint Safety Implementation Team (JSIT). The Turbulence JSAT endeavored to remain faithful to the JSAT process while confronting issues unique to the analysis and evaluation of turbulence accidents and incidents and their interventions. On several occasions the Turbulence JSAT co-chairs met with CAST process leadership to ensure compliance with the JSAT process.

3.1 Process Steps

3.1.1 Team Establishment/Structure

The Turbulence JSAT first met in October 1999 to establish the team, conduct training and review data sources. The JSAT was comprised of Government and industry representatives from most of the resident CAST organizations, as well as many other approved specialists representing appropriate operational disciplines. The organizational tally included:

- Airbus Industrie
- Airline Dispatchers Federation (ADF)
- Air Line Pilots Association (ALPA)
- Air Transport Association (ATA)
- Allied Pilots Association (APA)
- Association of Flight Attendants (AFA)
- Association of Professional Flight Attendants (APFA)
- The Boeing Aircraft Company
- Department of Defense (DOD)
- Federal Aviation Administration (FAA) comprising members from
    - Flight Standards (AFS)
    - Air Traffic Planning and Procedures (ATP)

    - Aviation Weather (ARW)
    - Aviation Research (AAR)
    - System Safety (ASY)
    - Accident Investigations (AAI)
    - Civil Aeromedical Institute (CAMI)
- Honeywell (formerly Allied Signal)
- International Association of Machinists (IAM)
- National Aeronautics and Space Administration (NASA)
- National Air Traffic Controllers Association (NATCA)
- National Association of Air Traffic Specialists (NAATS)
- National Oceanic and Atmospheric Administration (NOAA)
- Rockwell Collins
- University Corporation for Atmospheric Research (UCAR)

A complete list of JSAT members is provided in Appendix B.

The CAST assigned three co-chairs from FAA, NASA, and ALPA. In the interest of facilitating the analysis of the data available, the group was divided into three teams of 10 to 12 members each with a sub-team leader and deputy, spreading disciplinary representations as evenly as possible. FAA provided a facilitator for early discussions to insure that the objectives of the CAST process were met. The sub-teams remained intact during the entire assessment process from initial data review through intervention development and prioritization as described below.

3.1.2 Data Set Selection

The JSAT's goal was to develop interventions, which would lead to a reduction in the frequency of accidents, and injuries related to all forms of turbulence. The JSAT relied on accident and incident reports from accident investigative authorities, as those authorities employ internationally accepted definitions of "accident" and "serious injury." The team used narratives of turbulence accidents and incidents developed from NTSB and FAA files. Because the definition of 14 CFR 121 had changed in 1997, the team included turbulence accidents that occurred prior to 1997 in aircraft that head operated under 145 CFR 135 but which now would be subject to 14 CFR 121. The former 14 CFR 135 cases were treated as 14 CFR 121 cases throughout the process.

The following sets of accident and incident reports were reviewed at the October 2000 meeting.

<u>Accidents (149 cases)</u>

- 122 turbulence accidents and 5 wake turbulence accidents from 1983 through September 1999 involving US air carriers (source: NTSB).
- 9 turbulence accidents involving foreign carriers operating in US airspace (source: NTSB).
- 3 turbulence accidents involving foreign carriers operating outside US airspace (sources: Australian and British databases. Canadian and French databases also were searched, but no reports were found.)
- 10 turbulence mishaps involving military aircraft with civilian variants (source: DOD).

<u>Incidents (40 cases)</u>

- 23 turbulence and 11 wake turbulence incidents involving US carriers (source: NTSB).
- 4 turbulence incidents involving foreign carriers operating in US airspace (source: NTSB).
- 1 turbulence and 1 wake turbulence incidents involving foreign carriers operating outside US airspace (source: Australian and British databases).

Other team members provided accident/incident reports from NASA's Aviation Safety Reporting System (ASRS), the FAA's Accident and Incident Data System and reports from two air carriers. In addition, the team sought occupational safety data from two major air carriers and data from those carriers' Flight Operations Quality Assurance (FOQA) programs to begin quantifying the frequency with which normal flight operations involve abrupt increases in indicated airspeed, abrupt changes in pitch, roll, or yaw, etc. Additionally, the ATA and the DOD representatives provided several accident summaries. From the above data set a subset of 51 accidents and incidents was ultimately established as the data set used to develop the intervention strategies. The narratives of the 51 accidents and incidents are included in Appendix C.

3.1.3 Review of Data

At the first meeting, a sample accident was chosen and the co-chairs led a process overview using the sample as a template. In addition, a Runway Incursion JSAT member presented a summary of lessons-learned in that activity.

The team determined that some cases were not appropriate for analysis because they lacked adequate information.

FOQA is an excellent source of turbulence encounter information and at the outset of the JSAT it was anticipated that substantial insight would be gained from FOQA data analysis. Unfortunately, delays in negotiating a data non-disclosure agreement with affected carriers precluded the use of FOQA data. The JSAT recommends that the ATA be asked to lead an effort to address legal issues. One way to accomplish this may be through the development of a standardized industry-wide data non-disclosure agreement that is directed specifically to use of FOQA for research purposes commensurate, such as for the turbulence JSAT. An agreement of this type would facilitate obtaining the information from carriers for use by upcoming JSATs and the follow-on Turbulence JSIT.

In the end, NTSB accident and incident reports provided the primary data for the JSAT. Several of the ATA and DOD accidents were also included. Some of the cases were supplemented by available digital data from flight data recorders on aircraft involved in accidents and incidents and by data provided by the DOD on 10 mishaps in the military domain. The analysis was performed by dividing the data set among the sub-teams according to three chronological periods (1988-1993, 1994-1996, and 1997-1999).

3.1.4 Develop Characteristics/Indicators

In order to facilitate the analysis of the data set, each accident/incident was processed against a standard CAST list of accident characteristics and indicators at the December 1999 meeting. The Turbulence JSAT found it necessary to supplement the standard list in the areas of meteorological information, cabin crew activity, and air traffic control. Team consensus on Characteristics and Indicators was completed at the January 2000 meeting. The characteristics/indicators worksheet is provided in Appendix D.

3.1.5 Event Sequence Development

Event sequences were developed by the sub-team members to identify the series of events leading up to each accident/incident. The event sequences were used to help review, analyze and provide a common understanding of the accident/incident. Sub-teams began developing event sequences in the January 2000 meeting and completed that work individually or via conference call before the March 2000 meeting.

3.1.6 Identify Problems

At the March 2000 meeting, sub-teams formulated problem statements to describe situations in the event sequence that caused increased risk of turbulence injuries or where deficiencies were noted. Deficiencies included failure to follow procedures, equipment failures, maintenance failures, inappropriate crew responses and similar problems.

Contributing factors were also written during this meeting to help clarify the problem statements and explain why the problem occurred. Contributing factors helped focus on developing standard problem statements and intervention strategies.

3.1.7 Assign Standard Problem Statements

After identification of problems and contributing factors, standard problem statements were developed. Previously established CAST standard problem statements were reviewed and supplemented with turbulence-specific entries. Each sub-team developed new standard problem statements during the March 2000 meeting that fit the assigned accidents/incidents. A total of 21 Problems Statements resulted, of which nine were previously established in other JSATs.

CAST directed that the Turbulence JSAT use the 600 series for numbering both standard problem statements and interventions. After discussion with CAST process advisors, the team applied the numbering system to the new standard problem statements with a slight variation. The standard problem statements were divided into the seven groupings, each with a subset of the 600 series numbering. The groupings and their numbering are:

Flight Crew (60x), Cabin-Crew (61x), Air Traffic Control (62x), Aircraft Equipment (63x), Passenger (64x), Airline Operations (65x), Weather Information/Weather Providers (66x), and Type of Turbulence (67x).

The revised standard problem statements were then accepted by the entire JSAT group at the May 2000 meeting and incorporated into the accidents/incidents. A list of the standard problem statements and definitions are provided in Appendix E.

The Team Leaders developed a matrix to show the distribution of problem statements across the data set. That summary is in Appendix F. Additionally, the Team Leaders developed a matrix to show the distribution of injury and deaths across the data set. Appendix G is the injury summary and shows flight attendant and passenger injuries, with both divided into serious or minor, as defined by the NTSB. Fatalities are also included.

3.1.8 Identify Intervention Strategies

Intervention strategies were developed by each sub-team during the April 2000 meeting to address the standard problem statements in the assigned accidents/incidents. Each standard problem statement generated one or more interventions. The intervention strategies of the three sub-teams were again collated into a single set of interventions with broader application. This work was completed after the April meeting and was accepted by the JSAT at the May meeting. A total of 39 intervention strategies were adopted and applied to the standard problem statements to check for applicability. Some accident/incident cases were removed from the process at this point when it was determined that inadequate data precluded a clear understanding of the events. The final stages of the JSAT process were applied only to these remaining 51 cases. The intervention strategies are in Appendix H. The Team Leaders developed a matrix to show the distribution of intervention summaries across the data set. That summary is Appendix I.

3.1.9 Global Review of Characteristics/Indicators

Although characteristics and indicators are assigned and reviewed at the individual accident/incident level, the JSAT periodically took a big picture approach by looking at the characteristics and indicators as tools to ensure that individual characteristics and indicators were truly representative of the scope of the turbulence problem. Figure 4, which will be discussed in Section 4, depicts this approach.

3.1.10 Evaluate Intervention Effectiveness

At the May 2000 meeting, following a tutorial on rating intervention strategies, each of the sub-teams rated its assigned cases according to their Power, Confidence and Applicability (PCA).

In the first round of rating, each intervention strategy was rated against the specific problem and contributing factors within each event in each case. Some sub teams did this in a group session; others used individual raters within the sub team. At the conclusion of this round, every intervention had a PCA rating each time it appeared in each case. As a result, most interventions had multiple PCA ratings; that is, an intervention was applied more than once in a case.

In a second round of rating during the same meeting, all intervention strategies with multiple PCA ratings within a case were reviewed to consolidate one PCA rating per intervention per case. At the conclusion of this second round of rating, consensus was achieved on each intervention rating within a case.

Subsequent to the May 2000 meeting, the Turbulence JSAT co-chairs reviewed the PCAs to determine whether or not there was a sub-team bias that would skew the overall results. The co-chairs conducted a statistical analysis of the sub-team scores to reveal any sub-team biases that might impact the results by inadvertently weighting the results of one sub-team more heavily than another. As might be expected, there were some modest variations in the means and standard deviations between the sub-teams. To remove the small differences between the sub-team results all scores were converted to "standard scores" (as defined in statistical texts) and the results were revisited. The team determined that converting the scores to "standard scores" would effectively remove the sub-team biases. But it was also recognized that the sub-team biases would have no measurable affect on the final scores. The team was satisfied that the JSAT could move forward and the CAST process advisors agreed with that determination.

The final step in evaluating intervention effectiveness was to consolidate the PCA scores for a specific intervention across all cases into one PCA score. The desired result was a single PCA score for each intervention.

At the June 2000 meeting an attempt was made to use the CAST procedure to obtain the single PCA for each intervention. During the group attempt at consensus, it was apparent that the three sub-teams differed in interpretations of the meanings of the P, C, and A scores. Additionally several team members questioned assumptions being made about the interventions. It was clear that (1) some of the interventions needed to be edited for clarification and (2) the P, C, and A definitions needed to be reviewed. The co-chairs and team leaders met with the CAST process advisors after the June 2000 meeting. That meeting helped to clarify what needed to be done to complete the intervention ratings.

After the June meeting, a small group of the JSAT, consisting of the co-chairs, team leaders and representatives from each sub-team, met in Denver to clarify and consolidate the interventions. The result of that meeting was a refinement of the interventions and consolidation from 39 interventions to 30. The 30 interventions were then accepted by the JSAT at the August 2000 meeting in which team members reached consensus on the single PCA rating for each intervention. This resulted in one PCA rating for each of the 30 interventions.

3.1.11 Prioritize Interventions

Several schemes were used to develop effectiveness ratings for each intervention. These schemes were as follows: (1) the average Power, Confidence and Applicability ratings for each intervention were run through the standard CAST formula of:

$$\text{Overall Effectiveness (OE)} = P \times C/6 \times A/6$$

to derive an effectiveness rating. (2) only the cases with the top power ratings for each intervention were used to develop average P, C and A ratings which were then run through the formula to derive an effectiveness rating. (3) only those cases with Power ratings at or above the mean Power rating for an intervention were used to develop average P, C and A ratings which were then run through the effectiveness rating formula. (4) only those cases with Power ratings at or above the mean Power rating for each intervention (after rounding up to nearest whole number) were used to develop average P, C and A ratings which then yielded an effectiveness rating when run through the CAST formula.

It was not apparent which scheme would be best, so the JSAT asked its sub teams to exercise each scheme. The effectiveness ratings and relative rankings of the 30 interventions varied markedly among the various schemes, so the JSAT had to select one as a starting point for further consideration of intervention effectiveness. It was agreed that the second scheme was closest to the standard CAST method for determining Overall Effectiveness and this approach was selected.

To assist the JSAT in computing OE scores, each intervention was arrayed across accident cases for which it was specified, and effectiveness ratings were computed using the standard CAST formula for each case. In addition, average Power, Confidence and Applicability scores were computed for each intervention.

At its final meeting in August 2000, the JSAT scored PCAs across all cases for the 30 refined interventions. The intervention strategies, sorted by score, are in Appendix J. The assembled team voted individually on each intervention for each element – Power, Confidence and Applicability. Injury data linked to intervention effectiveness, as shown in Appendix G, was used during this process. Overall Effectiveness (OE) scores were then derived using the JSAT algorithm (OE = P x C/6 x A/6). A check for reasonableness resulted in no change to the OE ranking of the interventions.

One team leader led the voting exercise, and a color card voting method was used to aid vote counters with the scoring for each round. The group achieved consensus by averaging scores at one decimal point. Scoring was tallied as each round of voting was completed, and the ranking table was developed automatically. Results were available for immediate review at the completion of the final round. A sanity check of the final listing was accomplished by listing standard deviations to insure that the scoring made sense. The team was satisfied that the process had met the goal, and took a positive "thumbs-up" vote to accept the OE ranking of the interventions.

3.1.12 Technical Review

A panel of government and industry executives conducted a technical review. They included: Mr. Charlie Bergman, Staff Engineer, Engineering and Air Safety Department, ALPA; Mr. Keith Hagy, Manager, Engineering Accident/Investigator, Engineering and Air Safety Department, ALPA; Mr. Michael S. Lewis, Program Manager, Aviation Safety Program, NASA; Dr. John McCarthy, Ph.D., Manager for Scientific and Technical Program Development, Marine Meteorology Division, Naval Research Laboratory; Dr. Frances Sherertz, Deputy Director, Aviation Weather Directorate, FAA; and Mr. Bob Sutton, President, Aviation Research , Inc., consulting to the NASA Aviation Safety Program.

4.0 ANALYSIS OF DATA

This section presents an interpretation of the problem statements, the interventions and the priority of the interventions. It does not alter the findings of the Turbulence JSAT. It simply provides an overall construct for interpreting the results of the JSAT's work.

4.1 Problem Statements

Flight operations through areas of turbulence can result in three possible scenarios: a no-risk scenario, a low-risk scenario, and a high-risk scenario. In the *no-risk* scenario, the flight planner and flight crew successfully avoided forecasted or reported turbulence on the nominally "normal" flight path. In the *low-risk* scenario, the flight crew may knowingly penetrate turbulence, doing so while all equipment is stowed and all passengers and crew are seated and restrained. In the *high-risk* scenario, the flight planner and flight crew have no knowledge of the turbulence, or know of it and choose to ignore it, planning and operating directly through it without taking any special precautions in terms of stowing equipment or seating and belting passengers and cabin crew. These three scenarios are described below along with references to the standard problem statements developed by the Turbulence JSAT.

Note that the descriptions of the scenarios below are illustrated using Figure 6, a Turbulence Avoidance and Mitigation Flow Chart. The Flow Chart was developed as a tool to capture and organize information from the accidents and reveal useful patterns. These patterns suggested an overall flow chart of how turbulence accidents may or may not occur. The JSAT found it useful to develop the flow chart to organize the information and reduce duplication. The flow chart became particularly helpful in developing standard problem statements.

To develop each of the No Risk, Low Risk and High Risk Scenarios, Figures 6a, 6b, and 6c have been shaded to highlight the flow and the individual steps of that scenario.

4.1.1 The No-Risk Scenario

In the no-risk scenario, the aircraft completely avoids turbulence. Complete avoidance can be achieved via two paths in Figure 5. The first path is depicted in steps 1, 2, 3, and 4 in the Figure. In this scenario, the flight planner has and uses a valid strategic forecast that tells him/her the location and severity of turbulence, and the flight planner has an alternate route that is both free of turbulence and practical.

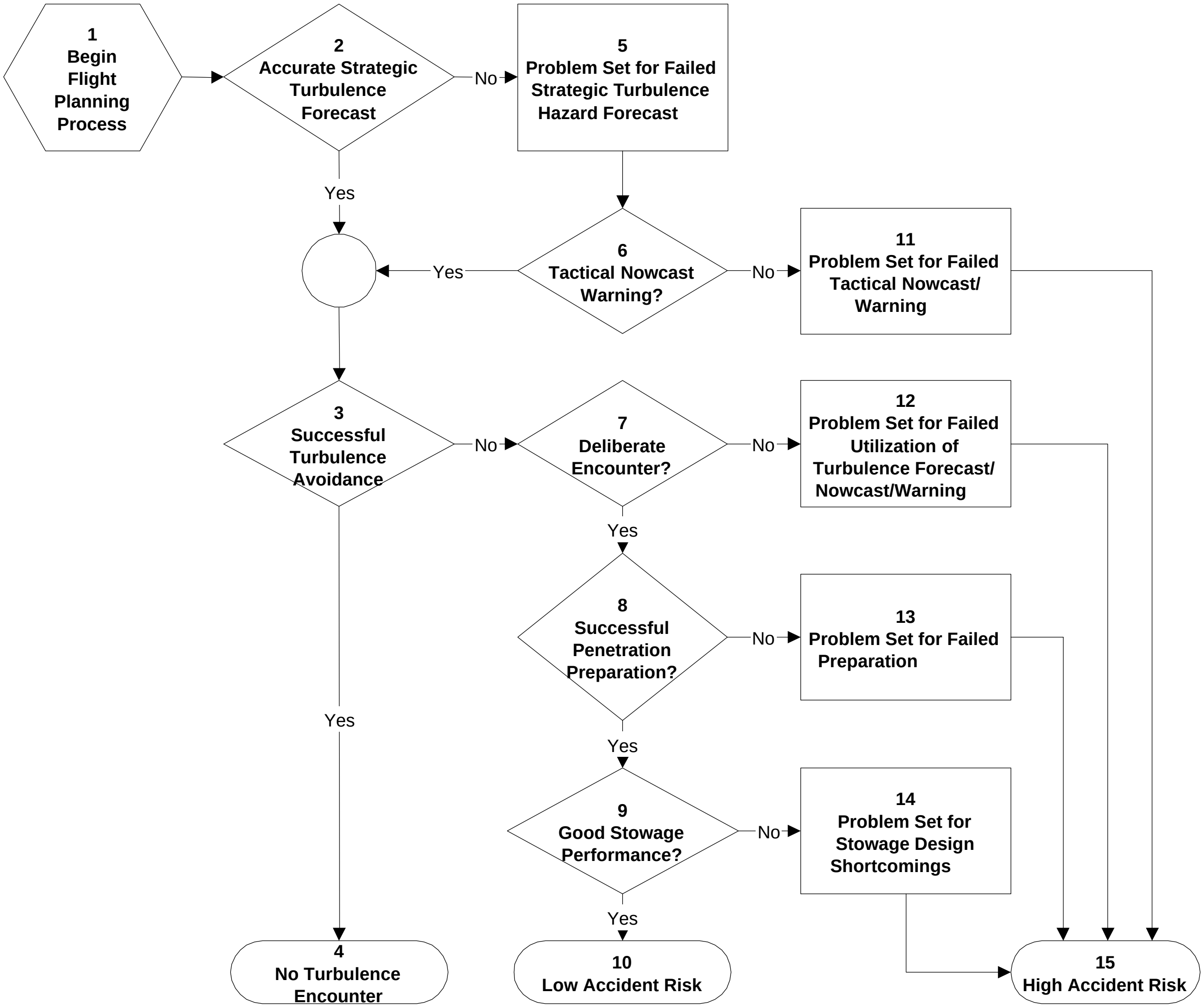

Figure 6: Turbulence Avoidance and Mitigation Flow Chart

The second path to successful avoidance of the turbulence is via steps 1, 2, 5, 6, 3, and 4 in Figure 6. In this scenario, the flight planner does not have a reliable strategic turbulence forecast, but a sound tactical turbulence nowcast or warning becomes available during the flight sufficiently ahead of the turbulence, that an in-flight diversion around the turbulence is executed.

In reviewing turbulence accidents, the JSAT documented a series of problems leading to failure of flight planners to flight plan or deviate around turbulence. These problems are categorized as follows: (1) turbulence forecasts and warnings are inaccurate, missing or late (2) flight planners and/or flight crew overlook valid turbulence information and select turbulent routes or (3) there are impediments to changing a route to avoid the turbulence.

(1) Inaccurate, missing or late forecasts and warnings are caused by:

- inability of government or private forecasters to produce forecasts [SPS #661]
- inadequate sharing of turbulence information among Airline Operations Centers (AOC) or the air traffic management infrastructure [SPS #653]
- inadequate collection, analysis, and dissemination of PIREPs and other relevant weather information to flight crews [SPS #623 & SPS #651]

- lack of real-time turbulence detection and warning systems [SPS #662]

(2) Decisions to take or to continue on a turbulent route, in spite of sound turbulence information, are caused by:
- lack of, or inadequate airline culture, policies, and procedures that encourage turbulence avoidance and mitigation during pre-flight and in-flight [SPS #654]
- failure of air carriers to effectively use available weather information in their routing decision making [SPS #652]
- failure of the flight crew to process and interpret available weather data relevant to their route [SPS #601]
- inadequate preparation in terms of briefings, understanding of weather information received, and awareness of the turbulence hazard on the part of the flight crew to make sound turbulence avoidance decisions [SPS #604]
- failure of dispatch or flight crews to follow procedures [SPS # 603] to avoid turbulence
- failure of ATC to ensure adequate in-trail separation behind aircraft that generate wake turbulence [SPS #621]
- lack of ATS/Air carriers CDM process and procedures that would produce a reliable CDM routing to avoid turbulence [SPS #624]
- lack of turbulence avoidance or mitigation training for all crew members and dispatchers [SPS #655]
- lack of recognition by flight crew of likely turbulence hazards caused by the wake of nearby aircraft [SPS #672], mountain waves [SPS #674], nearby convection [SPS #671], or, in climb-out and descent, nearby terrain [SPS #675]

(3) Impediments to changing a route to avoid the turbulence include ATC delay in processing clearance requests in a timely manner in both domestic and oceanic airspace [SPS #622].

4.1.2 The Low-Risk Scenario

The low-risk scenario, as depicted in Figure 6a, entails deliberate penetration of turbulence but with a secure cabin. A secure cabin means all equipment is secured and all passengers and cabin crew are seated and properly restrained before penetrating the turbulence. Deliberate penetration with a secure cabin follows one of two paths in Figure 6. The first and most direct path is via steps 1, 2, 3, 7, 8, 9, and 10. The second is via steps 1, 2, 5, 6, 3, 7, 8, 9, and 10. If equipment is unsecured when turbulence penetrations occur, collisions between equipment and people may cause injuries. If passengers or cabin crew are unrestrained when turbulence penetration occurs, they may be knocked off their feet or thrown to the floor, the ceiling, laterally against seats, other structures, or each other.

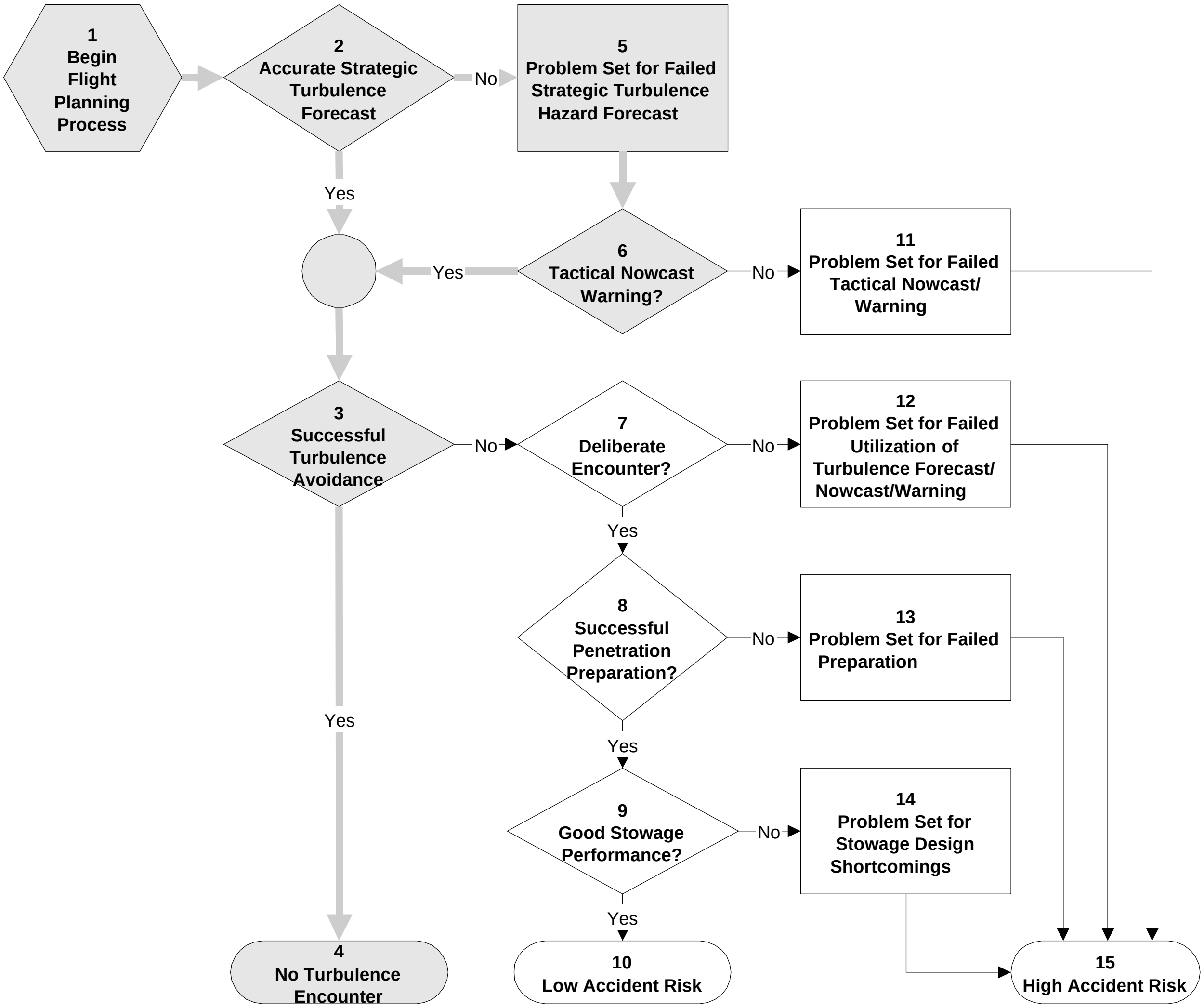

Figure 6a: Turbulence Avoidance and Mitigation Flow Chart -- No-Risk Scenario

Failure to secure the cabin, cabin crew, and passengers may be caused by:

- *flight* crew failure to communicate to cabin crew and/or passengers turbulence warnings or directions to be seated/restrained [SPS #602]
- *cabin* crew failure to communicate to passengers turbulence warnings or directions to be seated/belted [SPS #612]
- flight attendant not seated or not belted when seated due to inadequate warning time and/or conflict with other duties [SPS #611]
- aircraft or equipment design shortcomings that prevent timely storage of equipment [SPS #632]
- failure by cabin crew to follow procedures to prevent injury to themselves or to passengers [SPS #603]
- aircraft design shortcomings that lead to failure of restraints or overhead bin doors [SPS #631]
- Willful failure by flight attendants or passengers to comply with turbulence warnings [SPS #641]

4.1.3 High Risk Scenario

In the high-risk scenario, no warning of turbulence is available to the flight crew, the cabin crew, or the passengers. This scenario comes about due to a total breakdown in producing, communicating or heeding turbulence forecasts or warnings so that the turbulence encountered is completely unanticipated. Path 1,2,3,7,12,15; path 1,2,3,7,8,13,15; path 1,2,3,7,8,9,14,15; path 1,2,5,6,11,15; path 1,2,5,6,3,7,12,15; path 1,2,5,6,3,7,8,13,15; and path 1,2,5,6,3,7,8,9,14,15 all lead to the high-risk scenario. Under this scenario, there may be no preparation for a turbulence encounter by flight crew, cabin crew, or passengers. If cabin crew and/or passengers are unsecured, the only measures that can mitigate injuries under this scenario involve aircraft design. Design or redesign measures include passive or automatic controls (which the pilot does not manipulate) to dampen the effects of turbulence, and cabin design for emergency handholds and injury-mitigating surfaces.

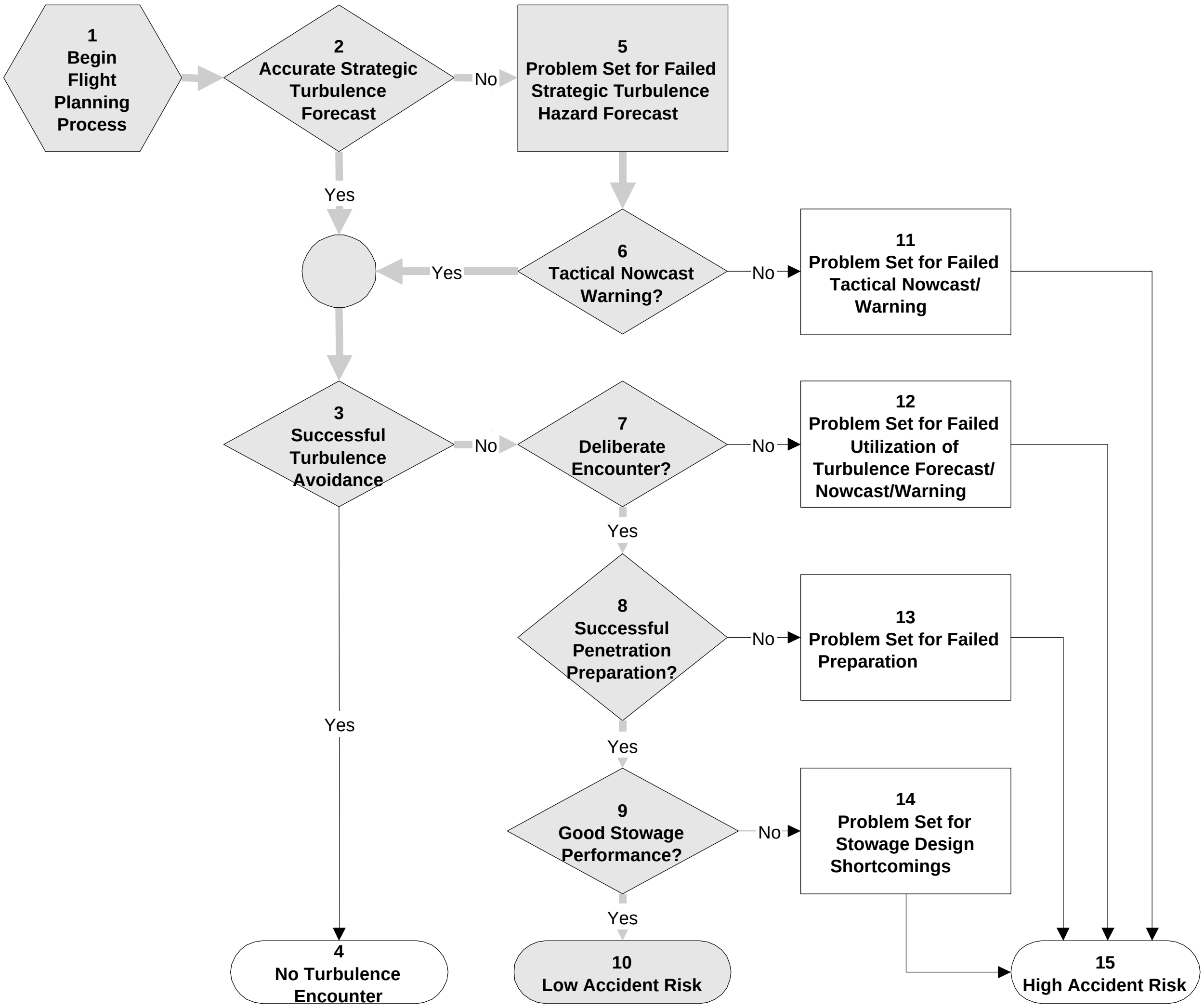

Figure 6b: Turbulence Avoidance and Mitigation Flow Chart -- Low-Risk Scenario

Some failures to mitigate injuries in the high-risk scenario are due to aircraft design elements insufficient to mitigate injuries in unanticipated turbulence [SPS #631]. These failures may include:

- Lack of automated flight controls designed to dampen the effects of turbulence without pilot intervention
- Lack of emergency handholds in the cabin for use by cabin crew and passengers who are not seated and restrained during turbulence
- Cabin structures that have hard or angular surfaces, corners or protrusions
- Restraints or overhead bin doors that may fail during turbulence

4.2 Interventions

The interventions fall into two major categories as depicted in Figure 6c: (1) avoidance of turbulence encounters, and (2) mitigating the ipact of turbulence on aircraft occupants. The previous section presented groups of problems associated with different phases of operations in the presence or absence of turbulence information and in the differing ways operators choose to use or not use turbulence information. This section discusses the interventions designed to address those problems.

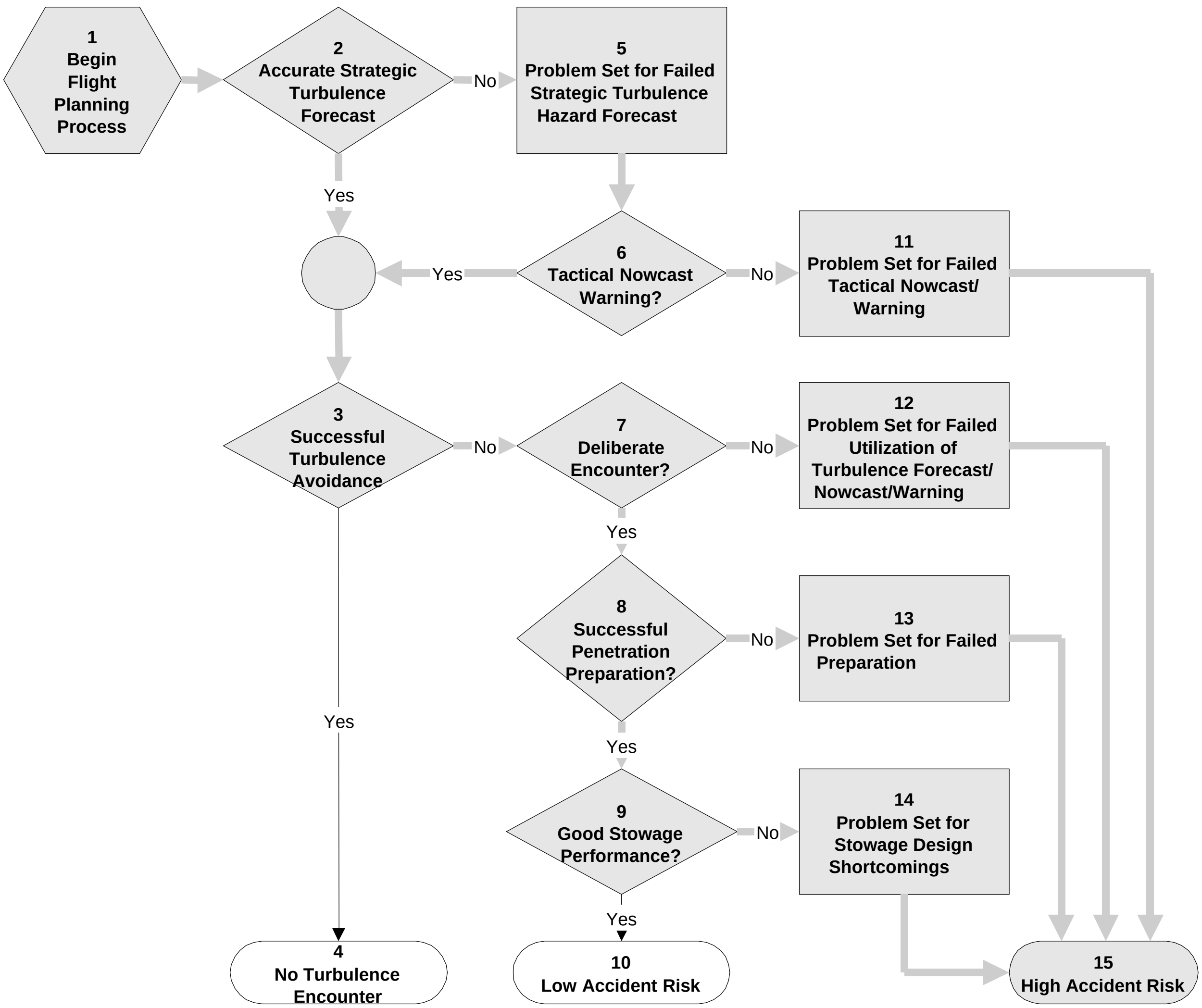

Figure 6c: Turbulence Avoidance and Mitigation Flow Chart -- High-Risk Scenario

4.2.1 Avoid Turbulence Encounters

Clearly the optimum overall solution to avoid turbulence injuries and fatalities is to avoid turbulence altogether. There are three fundamental intervention sets needed to avoid turbulence. They are (1) improve turbulence information available to decision makers in pre-flight and in-flight stages, (2) improve pre-flight/in-flight decision making for turbulence avoidance, and (3) improve route selection options, especially in the oceanic regime.

4.2.1.1 Improve Weather Information For Pre-flight And In-Flight Turbulence Avoidance Decisions

Assuming there are turbulence-free and practical alternate routes available, the most effective way to avoid turbulence injuries and fatalities would be to develop a flight plan around the turbulence or, once in flight, to deviate around it or make an appropriate altitude change. Reliable information about the location and severity of turbulence is needed to make these turbulence avoidance decisions. A number of specific interventions drawn from the turbulence cases studies that would address this need area are listed below:

Note: there are two notations after the text of each intervention in the list. The notation [I#616] means intervention number 616, and the notation (OES3.9) means an Overall Effectiveness score of 3.9. Note that the OE scores ranged from a high of 3.9 to a low of 0.8 with a mean OE score of 2.1 and a median OE score between 2.0 and 1.8. See Appendix H for the full text of the interventions. See Appendix J for the Overall Effectiveness scores.

(1) Implement "best practices" in all air carriers as outlined in Advisory Circular (AC) 00-30b, to include full in-house or vendor-supplied meteorological capabilities and a turbulence charting and alerting program [I#616, OES 3.9]

(2) Improve quantity and timeliness of PIREPs available to pilots, dispatchers and forecasters as an important source of information about the location and intensity of turbulence.
- Airline Operations Centers (AOCs) should improve on sharing of PIREPs [I#617, OES2.3].
- More manual PIREPs should be taken and disseminated throughout the system [I#618, OES2.0].

(3) Improve turbulence detection.
- Implement automated turbulence report collection/dissemination [I#621, OES3.3].
- Develop and implement a look-ahead detection capability on aircraft [I#628, OES3.2]
- Improve detection of low reflectivity thunderstorms that are often the source of turbulence encounters [I#612, OES1.8].

(4) Improve turbulence forecasting.
- Improve the forecasts themselves [I#619, OES2.9].
- Institute a CDM) focus for turbulence forecasting as is being done today with convection via the Collaborative Convective Forecast Product (CCFP) [I#620, OES1.6].

(5) Improve the overall utility of turbulence products for decision-makers.
- Develop real-time graphical weather products and turbulence alerts for dissemination to flight deck [I#613, OES2.9]
- Develop and implement a turbulence product that is a synthesis of airborne and ground based sensors and forecasts that clearly depicts the location and intensity of turbulence [I#614, OES2.6].
- Assure consistent terminology and data content for turbulence products to ATC, dispatchers and flight crews [I#615, OES1.0].

4.2.1.2 Improve Pre-flight/In-Flight Decision Making For Turbulence Avoidance

Even when good information on turbulence location and intensity is available in advance, there are significant failures on the part of decision-makers to properly use that information in the avoidance of turbulence. A number of specific interventions drawn from the turbulence cases studied that would address this need are listed below.

(1) Government and industry should develop and implement better guidance for remaining clear of the buffer zones around thunderstorms to reduce turbulence accidents associated with flying too close to those storms [I#608, OES2.2].

(2) Air carriers should provide adequate initial and recurrent training to flight crews on fundamental understanding of turbulence assessment, recognition, and avoidance [I#609, OES2.1].

(3) Government and industry should employ and jointly train for CDM for improved turbulence forecasts; consistent turbulence information for dispatch, ATC and flight crews; and improved pre-flight/in-flight decision making [I#610, OES2.0].

(4) Air carriers need to ensure they acquire and make better use of currently available products, including SIGMETs, PIREPs, and AIRMETs, and other services including Flight Watch and HIWAS [I#607, OES1.7]

4.2.1.3 Improve Pre-Flight And In-Flight Oceanic Route Selection Options

ATC should allow greater flexibility in oceanic route (including altitude) selection to enable better turbulence avoidance [I#611, OES1.1]

4.2.2 Mitigate Impact Of Turbulence On Aircraft Occupants

Often turbulence can not be avoided, either because the information about its location and intensity is not available or adequate, or there are no completely turbulence-free routes. In these cases, active or passive measures to mitigate the impact of turbulence are the best tools to lower injury and fatality rates. These measures are generally classified into (1) reduction of passenger exposure, (2) reduction of flight attendant exposure, (3) reduction of both passenger and cabin crew exposure, and (4) redesign of aircraft flight controls to dampen the effects of turbulence.

4.2.2.1 Reduce *Passenger* Exposure To Inadvertent Turbulence

The best way to reduce passenger exposure to inadvertent turbulence is through better compliance with seating and seat belt directions. The specific interventions drawn from analyzed turbulence cases that would address this need area are listed below.

(1) FAA should require air carriers to standardize procedures and phraseology for pre-flight and in-flight, flight crew to cabin crew communications about turbulence hazards, severity, and all-clear declarations [I#601, OES2.9].

(2) Air carriers should develop and implement instant, two-way communications capability between flight crew and cabin crew anywhere in the aircraft at all times to improve timeliness and effectiveness of turbulence warnings and damage assessments [I#602, OES1.8].

(3) Air carriers and government should develop and implement enforcement policies, procedures, and perhaps systems to improve passenger compliance with seating and seat-belt instructions from crew [I#604, OES1.8].

(4) Air carriers should develop and implement automated aural or visual cabin alerting systems for immediate warning of imminent turbulence to cabin crew and passengers {I#605, OES1.7].

(5) DOT, FAA and air carriers should implement a public awareness campaign, e.g., an extension of the Vince and Larry Seat Belt Campaign, to improve passengers' understanding of turbulence risks and the need for seat belt compliance [I#630, OES1.5].

(6) Air carriers should develop and implement standardized pre-flight briefings, including multi-lingual briefings where appropriate, to provide practical information about anticipated turbulence hazards and the passengers' responsibility for seat belt compliance [I#603, OES1.3].

4.2.2.2 Reduce *Flight Attendant* Exposure To Inadvertent Turbulence

A disproportionately high incidence of turbulence injuries among flight attendants makes it important to find ways to reduce their exposure to inadvertent turbulence. The specific interventions drawn from the turbulence cases studied that would address this need area are listed below.

(1) Air carriers should establish and implement policies and procedures requiring flight attendants to be seated and restrained from takeoff to cruise altitude and from FL200 through landing in order to reduce unrestrained time during potential or actual turbulence [I#622, OES3.6].

(2) FAA should require, and air carriers should develop and implement policies and SOPs that permit flight attendants to prioritize immediate duties and cabin service schedules, including the option to remain seated while making seatbelt announcements after warnings of imminent turbulence [I#623, OES2.7].

(3) FAA should require and air carriers should develop and implement flight attendant training to increase flight attendant understanding of their responsibility for their own safety in the context of turbulence hazards and aircraft behavior in turbulence [I#624, OES2.0].

4.2.2.3 Reduce *Both* Passenger And Flight Attendant Exposure To Inadvertent Turbulence

Some measures work to reduce exposure by both passengers and flight attendants. The specific interventions drawn from the turbulence cases studied that would address this need area are listed below.

(1) FAA should require, and air carriers and manufacturers should equip, cabin interiors with handholds, other restraint systems, padding of hard or angular surfaces (galleys, arms rests, etc), and additional jump-seating. [I#625, OES1.8].

(2) Manufacturers and air carriers should redesign, test and implement systems for easier, faster and more comprehensive securing of service equipment [I#629, OES1.5].

(3) Air carriers and manufacturers should consider redesign of seating restraint systems for flight attendants and passengers including small children [I#626, OES1.1].

(4) Manufacturers should evaluate and redesign overhead storage bins for improved integrity during turbulence and evaluate the hazards associated with other items suspended from the ceiling [I#627, OES0.8].

4.2.2.4 Redesign Of Aircraft Flight Controls To Dampen The Effects Of Turbulence

The effects of turbulence on the aircraft and its occupants can be lessened or exacerbated by manipulation of flight controls and adjustments in airspeed. These manipulations and adjustments can be done manually or, if properly designed, automatically. In some instances, manual responses by flight crews have actually worsened the effects.

The intervention in this area is for researchers, manufacturers and air carriers to develop and implement automated aircraft flight control and airspeed adjustment capabilities to dampen the effect of turbulence on the aircraft [I#606, OER#21].

4.3 Recommended Intervention Sets

The JSAT has examined individual interventions and their Overall Effectiveness Rank and Scores. It has also presented the interventions in relationship to groupings of the standard problems they are intended to resolve. In this section, we note that there are sets of interventions that share common purposes and that score relatively close together in OES. The JSAT recommends four such sets, whose OES cluster relatively high, for priority consideration by the JSIT. An intervention is thought to score relatively high if its OES is above 2.1, which is the mean OES for all interventions.

Note that the other interventions not clustered under these four recommendations are considered viable on their own merits. They should be carefully considered by the JSIT as well. Note that some interventions are omitted from this analysis because they do not meet the criteria.

Recommendation 1: Improve The Use Of Available Information

The Turbulence JSAT determined that the best way to reduce turbulence injuries is for air carriers to implement a focused program of avoiding turbulence in the first place and the best way to avoid turbulence encounters is through better utilization of currently available information about turbulence. Accordingly, the set of interventions that had to do with improved acquisition, display, synthesis, and sharing of current information as well as those that would yield better interpretation and understanding of currently available information scored highest as a group. These interventions are listed below in order of their OESs.

- Implement current best practices across the industry, as outlined in Advisory Circular (AC) 00-30B (I#616, OES3.9).
- Improve displays of current information [I#613, OES2.9].
- Improve synthesis of currently available airborne and ground-based data [I#614, OES2.5].
- Improve sharing of PIREPs and other time-critical data [I#617, OES2.3].
- Provide better guidelines on the buffer between aircraft and thunderstorms to be maintained by pilots [I#608, OES2.3].
- Implement a CDM process to improve the use of turbulence information in flight planning and in-flight decision making [I#610, OES2.2].
- Improve training on the fundamentals of turbulence assessment, recognition, and avoidance [I#609, OES 2.1].
- Increase use of SIGMETS, PIREPS, AIRMETS, and Flight Watch and HIWAS services [I#607, OES1.7].

Recommendation 2: Improve Information About The Location And Severity Of Turbulence.

The JSAT gave high ratings to another set of interventions that had the potential to help avoid turbulence altogether by improving information about the location and severity of turbulence.

- Improve immediate warning of turbulence through look-ahead sensors [I#628, OES3.1].
- Implement automated, on-board turbulence measurements that are reported in real-time to other users (e.g., trailing aircraft) [I#621, OES3.0].
- Improve turbulence forecast accuracy [I#619, OES2.8].
- Provide additional manual PIREPS [I#618, OES2.0].
- Improve detection of low reflectivity thunderstorms [I#612, OES1.8].
- Improve forecasts through a CDM process analogous to the current CCFP [I#620, OES1.6]

Recommendation 3: Improve Risk Management For Flight Attendants

The JSAT found that flight attendants experienced the highest injury rate of all of those exposed to turbulence. Consequently, another set of interventions aimed at reducing injuries among flight attendants was created. This set of interventions would, collectively, provide better risk management for flight attendants in the performance of their duties:

- Procedures should be promulgated for flight attendants to remain seated from takeoff to cruise and from FL200 to landing to reduce their exposure to turbulence during these vulnerable phases of flight [I#622, OES3.6]
- Flight attendants should be empowered to prioritize seat belt monitoring duties and cabin service and to place a higher priority on their own safety [I#623, OES2.7]
- Air carriers should provide better training of flight attendants to increase their understanding of their responsibility for their own safety in the context of turbulence hazards and aircraft behavior during turbulence [I#624, OES2.0]

Recommendation 4: Improve Communications

The final set of interventions that had a high potential to reduce turbulence injuries has a common theme of communications. Improvement in communications between the flight deck and the cabin crew, between the flight deck and passengers, and between the flight attendants and passengers all have the potential to reduce turbulence injuries.

- Improved communications procedures and phraseology between flight and cabin crew to make the turbulence warning process work more effectively, resulting in better protection of flight attendants and passengers [I#601, OES2.9]

- Implement two-way instant communications capability between flight crew and cabin crew to improve timeliness and effectiveness of turbulence warnings and damage assessments [I#602, OES1.8].
- Enforcement of passenger compliance with seating and seat-belting instructions from crew [I#604, OES1.8].
- Implement a system of visual and aural turbulence alerts [I#605, OES1.7]

The intervention strategies that meet the above criteria are sorted by category and included in Appendix K.

5.0 On-Going Activities of Potential Interest To The JSIT.

There are two activities that may be of interest that could not be captured in time for use in the Turbulence JSAT. They are Flight Operations Quality Assurance (FOQA) and the Secure Cabin Drill.

5.1 FOQA

Sensitivities to litigation and possible punitive actions against pilots and air carriers have effectively embargoed the availability of FOQA data for JSAT use. This is unfortunate because FOQA data can provide insights on actions to avoid accidents. In this JSAT, data collected during severe turbulence encounters that do not result in injuries could provide positive clues toward developing more effective interventions.

The issues of enforcement immunity for pilots and air carriers must be resolved before FOQA data can be usefully available for JSAT or JSIT analysis. Industry action will be necessary to develop a standardized non-disclosure agreement that will permit JSAT/JSIT use.

5.2 Secure Cabin Drill

For the follow-on Turbulence JSIT to establish the benefit of a reliable turbulence warning, the JSIT should clearly understand the warning time requirements based on the reality of the aircraft cabin environment. Without a reliable turbulence warning mechanism (currently a high false alarm rate and often no warning of real turbulence encounters), neither crews nor vendors of safety technology have been challenged to devise rapid means for configuring aircraft cabins for safe transition through turbulence. The availability of a reliable turbulence detector/sensor is expected to stimulate the development of cabin procedures and technology for reducing the time required to secure the cabin. NASA is leading an effort that involves FAA, air carriers, and other organizations in the aviation industry to conduct a simulation of aircraft cabin preparation to establish a “secure cabin” time estimate and provide insight for developing more rapid preparation techniques.

New technology that provided about one minute of warning and a low false alarm rate has been demonstrated recently. Researchers are hopeful that increased warning times may eventually be possible, but it is important to establish realistic operational warning requirements against which to measure technology performance and to focus research activities.

A series of simulations of preparing an aircraft cabin for a turbulence encounter will be used to establish “secure cabin” time requirements. Actual aircraft cabins will be used to conduct the drill to add realism to the exercise. An experienced staff of cabin and flight deck crewmembers will devise the procedures. The cabin preparation activity will be performed using professional cabin crewmembers and volunteer passengers. Important factors to include in the cabin scenario include, as a minimum:

- Narrow body and wide-body aircraft hull configurations;
- Cabin-passenger load and associated flight attendant complement;
- Cabin Class (first class, main cabin, etc.);
- Cabin Activities (food service, heavy rest room utilization, night with passengers sleeping, etc.);
- Members of the passenger cast will be instructed to behave as if a reliable turbulence warning capability exists and that serious injury may result should they be unrestrained when the turbulence is encountered.

APPENDIX A JOINT SAFETY ANALYSIS (JSAT) CHARTER FOR TURBULENCE

Turbulence JSAT

I. PURPOSE

To review and analyze data and identify potential intervention strategies in order to enhance commercial aviation safety with regard to the hazards of atmospheric en route turbulence encounters including en route wake vortex.

II. BACKGROUND

Government and industry have agreed to work together, to identify and implement a data driven, benefit focused, safety enhancement program designed to continuously improve our safe commercial aviation system. To this end the Commercial Aviation Safety Team (CAST) was formed. The CAST has further agreed that cooperatively and selectively pursuing the critical few high leveraged safety intervention strategies will maximize the safety benefit to the flying public through a focused application of industry and government resources.

To achieve this goal, the CAST has agreed to charter a Joint Safety Analysis Team (JSAT) on Turbulence. Because the industry and CAST recognizes the unique nature of turbulence and the many injuries it causes during the conduct of commercial flight, the scope of this JSAT will encompass all aspects of turbulence including the forecasting and use of turbulence information by operators.

III. TASK

A. The team shall acquire available data, including prior studies and analyses. The data will be used to conduct a causal analysis to determine the proximate cause of fatalities and injuries within the NAS and to US FAR Part 121 operations worldwide.

   JSAT will collect all turbulence caused injury data available for the CAST baseline time frame. Information will include, but is not limited to the following:

   1. A collection of numbers and type of serious injuries/fatalities to passengers and flight crew.
   2. A clear, unambiguous, scientific validation of the turbulence encountered in the accident or incident.
   3. Forecasted turbulence conditions.
   4. Actual turbulence conditions.
   5. Location and time.
   6. Turbulence information and warnings disseminated to the pilots during planning and conduct of the flight.
   7. Aircraft type and available mitigation equipment.
   8. Meteorologist / dispatcher / crew proficiency/training level.
   9. Type, location, intensity, and duration of the turbulence encountered
   10. Actions taken by Cockpit and Cabin crew to avoid or mitigate the impact of the encounter
   11. Timeliness of warnings provided to cockpit and cabin crew
   12. Status of seatbelt sign.
   13. Passenger compliance with crew warnings.
   14. Number, severity, location on the aircraft, and cause of injuries.
   15. Medical attention provided inflight.

B. The team shall use the process defined in the JSAT Process Report to identify and document potential weather and turbulence intervention strategies, designed to prevent turbulence related injuries and evaluate the effectiveness of each strategy.

C. The process shall include a technical review as defined by the JSAT Process Report. Results of the technical review will be presented to the JSAT for consideration prior to final report submittal to CAST.

IV. PRODUCTS

The deliverables include reports to the CAST providing a summary of data analysis, possible intervention strategies, and an evaluation of the effectiveness of each strategy.

V. TIMING

The team will meet monthly for periods of approximately three days. It is expected that the final team report will be delivered to the CAST prior to August 31, 2000.

VI. MEMBERSHIP

The team will include representatives with the appropriate technical or operational background provided by industry and government. The membership is expected to include representatives of the CAST organizations involved in turbulence issues.

VII. RESOURCES

The participating organizations agree to provide the financial, logistic and personnel resources to carry out this charter.

APPENDIX B TEAM MEMBERSHIP
Turbulence JSAT

TEAM CO-CHAIRS

ROD BOGUE
Manager, Turbulence Element, NASA Aviation Safety Program
National Aeronautics and Space Administration

RICHARD J. HEUWINKEL
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TEAM LEADERS

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TIM GALLAGHER
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NOREENE KOAN
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Association of Flight Attendants, AFL-CIO

MIRO LEHKY
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DR. MOHAMMAD A. TAKALLU
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Federal Aviation Administration

DR. KEVIN WILLIAMS
Office of Aviation Medicine
Federal Aviation Administration

BRIAN WOZNIAK
Flight Attendant, Continental Airlines
International Association of Machinists

APPENDIX C DATA SET
Turbulence JSAT

The following sets of data were reviewed for use in the Turbulence JSAT. A subset of 51 accidents and incidents was later selected for the analysis conducted by this JSAT. Only the specific accidents/incidents used for analysis are included in this Appendix.

Note that three turbulence “commercial like” accidents involving Department of Defense aircraft and three accidents provided by a specific airline were also included in the analysis. However the narratives are not included for these six cases.

<u>Accidents</u>
122 turbulence accidents involving US air carriers anywhere in the world; these narratives are numbered 1 through 122, with a prefix of "ACC 121-122"

9 turbulence accidents involving foreign carriers while operating in the US; these narratives are numbered "ACC 129-123" through "ACC 129-131"

4 wake turbulence accidents involving US air carriers anywhere in the world; these narratives are numbered "ACC 121-132" through "ACC 121-135"

3 turbulence accidents involving foreign carriers operating outside US airspace; these narratives are numbered "ACC Foreign-136" through "ACC Foreign-138"

5 wake turbulence accidents involving foreign carriers operating outside US airspace; these accidents are numbered "ACC Foreign-139" through "ACC Foreign-143"

<u>Incidents</u>
23 turbulence incidents involving US carriers anywhere in the world (INC 121-1" through "INC 121-23")

4 turbulence incidents involving foreign carriers operating in US airspace ("INC 129-24" through "INC 129-27")

11 wake turbulence incidents involving US carriers ("INC 121-28" through "INC 129-38")

1 turbulence and 1 wake turbulence incident involving foreign carriers outside US airspace ("INC Foreign-39" and –40)

ACC 121-1 United Sep-30-99 Sparta, NJ
Airbus 319-131 Injuries: 1 serious, 44 uninjured.

At 1743 hours, a United A319-131 encountered turbulence in VMC over Sparta, New Jersey, enroute BOS-Dulles. Two pilots, 2 FAs, & 40 pax were uninjured. A third FA sustained a serious back injury.

The PIC reported occasional light turbulence at FL310 en route to IAD. About 15 minutes from IAD, a FA notified the PIC that another FA had struck door 2l with her neck and was unconscious. The PIC declared a medical emergency and requested that paramedics meet the flight upon landing.

According to the injured FA, the seat belt sign was "on", but no announcement had been made for the FAs to be seated. Two of the FAs had returned to their seats and the injured FA was locking a cart in the galley when she "felt a bump." as she was proceeding to her seat, they encountered another "bump" and she was thrown against the assist handle on the 2l door. She fell to the floor and became unconscious for 2 minutes. The other 2 FAs provided her with oxygen and placed blankets under her head. The injured FA remained in the same position on the floor until the flight landed. She then was transported by helicopter to a hospital. According to United, the FA suffered a herniated c-6 disk. She remained in the local hospital for 5 days, and was then moved to a different hospital.

ACC: 121-2 Continental Jul-08-99 Atlantic Ocean
Boeing 737-824 Injuries: 1 serious, 71 minor, 89 uninjured.

At 1510, a Continental 737-824 sustained minor damage in clear air turbulence in VMC cruise at FL290 about 180 miles south of Bermuda. One pax was seriously injured; all 4 FAs & 67 pax had minor injuries; 2 pilots & 87 pax were uninjured.

In a telephone interview, a safety official for Continental reported the airplane was in cruise at FL290 in smooth air with the seat belt sign off. He said the crew reported one jolt, and the airplane descended 500 feet. Due to possible injuries, the crew diverted to Bermuda (BDA) and landed at 1604.

In a written statement, the captain said: "approximately ten miles north of Pruit intersection on a523 at 29,000 ft. In clear air we encountered two severe jolts (turbulence). Our aircraft lost about 400 feet & was descending at 2,000 FPM. Speed was approaching MMO (maximum mach operating speed). I made a slow recovery back to 29,000, bottoming out our descent at 28,400. The seat belt sign was off and during recovery I placed it back on. When the aircraft was level we attempted to reach the flight attendants via the inter-phone, no response. I instructed my FO to go into the cabin and assess damages. He quickly informed me of numerous injuries. At that time I declared an emergency and diverted to Bermuda. Turning direct to BDA our location was 160 miles SSW. No reports of turbulence were reported by ATC along our route of flight or in our dispatched flight paper work."

In a written statement, the FO said "we were level at FL290. It had been smooth for 30 minutes [and] the seat belt sign was off, there were no visual cues to an adverse ride. Both radars were on (we had deviated to avoid weather earlier in the flight) when the aircraft was hit by two severe jolts in quick succession. The captain (pilot flying) recovered the aircraft from a nose down attitude, when the aircraft was once again level and on course the autopilot, [lateral] nav and [vertical] nav were re-selected."

In a written statement, a FA said: the crew had just completed the meal service and I was in the back of the aft of the main cabin [at] row 29 picking up trays from the meal service. The seat belt sign was off and we were flying through smooth air with no sign of turbulence. Then all of a sudden, the aircraft dropped abruptly, which caused my body to fly upward hitting my head on the ceiling. I fell back to the floor on my knees. Approximately 10 seconds later, the aircraft dropped again causing my head to hit the ceiling once again. At that point I lost consciousness. When I awoke, I was very dazed noticing my head bleeding, arms cut and bruised, and back and shoulders sore."

In a detailed written statement, a second FA described a similar sequence of events. She said people, carts, and equipment were tossed about and that she came to rest under a row of seats. She further described the crew coordination involved in treating and calming the pax and the communication from the cockpit to the cabin about the egress and treatment of pax upon arrival at Bermuda. Medical teams meet the airplane at BDA. Sixty-four pax and 4 FAs were examined at the hospital. One pax suffered a head laceration and a fractured rib.

The AFDR showed a sequence of events consistent with that described in the crew statements. A graph of several flight parameters indicated cruise flight at 29,000 feet with no change in heading, airspeed, or altitude for several minutes approaching the accident sequence. The altitude graph shows a slight climb before the airplane descends to 28,400 feet. A slow recovery to 29,000 feet with no oscillations was indicated by the graph line.

Vertical g forces sustained during the sequence varied in amplitude between a positive 2 g's and a negative 1 g. The elapsed time between the first altitude excursion to recovered cruise flight was approximately 75 seconds.

An NTSB review of infrared satellite imagery found that "the airplane was on the southern edge of a convective complex." entries in the airplane's maintenance log reflected completion of the turbulence inspection and damage to interior ceiling panels in row 25, 29, and in the aft galley.

ACC 121-4 United Jun-11-99 Madison, WI
Boeing 777-222 injuries: 1 serious, 5 minor, 290 uninjured.
At 2130 hours, a United 777-222 encountered clear air turbulence in VMC on descent near Madison, enroute MSP-ORD. One pax was seriously injured; 3 pax & 2 FAs received minor injuries. Two pilots, 8 FAs, & 280 pax were not injured. The airplane was not damaged. The flight continued to O'Hare.
The PIC said the flight was smooth before encountering the unexpected turbulence on descent thru FL180. He said the moderate turbulence lasted 20 to 30 seconds after which the remainder of the flight was smooth. The seat belt sign was not on at the time.

ACC 121-5 Vanguard Airlines May-05-99 Chicago
Boeing 737-222 injuries: 1 serious, 47 uninjured.
At 2220 hours, Vanguard Airlines 737-222 encountered turbulence on descent into Chicago Midway from MSP. One FA was seriously injured. The PIC, FO, 2 other FAs & 43 pax were not injured. The airplane was not damaged.

The PIC reported they encountered 30 seconds of moderate turbulence while deviating around weather cells on descent from 17,000. He said the seatbelt sign was on and that he had informed the FAs to clean up the cabin and prepare to sit down 10 minutes before the encounter. Ahe also said that 5 minutes later he informed the FAs to be seated immediately. Upon reaching FL100, the PIC was informed that 2 of the FAs had not been seated and were injured during the turbulence. The crew declared an emergency with ATC & the flight continued to Midway where it was met by medical personnel.

The "A" flight attendant who was in the front of the airplane reported that 30 minutes into the flight the PIC notified her that they may encounter turbulence and that the FAs should secure their galleys. She stated she informed the "B" and "C" FAs, and they secured the galleys. She made a PA announcement that they would be picking up service items. The "A" FA stated that at 15 minutes later she received another call from the cockpit stating that they should secure the cabin and take their seats. She stated she made the final prelanding PA announcement and they secured the cabin for landing. She stated that she was in the forward galley and FAs "B" and "C" were in the aft galley when they encountered the turbulence at which time she immediately got into her jumpseat. She stated that about a minute later the turbulence subsided and she made her way to the aft, where she found the "C" FA laying in the aisle and the "B" FA sitting in pax seat 21c. The "C" FA told her that she had hurt her hip and she wasn't sure she could walk. The "A" FA helped her off the floor and into seat 21d. She then noticed that the "B" FA was bleeding from a cut on her knee. She stated that she then went to the cockpit to inform the flight crew of what had happened.

The "B" and "C" FAs stated they were informed that turbulence was expected. About 5 minutes later, as they were securing the aft galley, they were informed to take their seats. They reported the turbulence was encountered as they were going to get in their jumpseats. The "B" FA reported that she grabbed the seatback in front of her & tried to get into a seat in row 21. She stated the airplane dropped and she was thrown to the ceiling where she hit her head. She then came down and landed on the back of seat 20c. The "C" FA was coming out of the aft galley to assist her when the airplane dropped again. The "C" FA was thrown to the ceiling and came back down into the aisle where she landed on her right side, hitting her back against a seat. They stated the "C" FA laid on the floor for 10 minutes until the "A" FA came from the forward section & helped her into a seat. The "B" FA suffered a cut on her knee and bruises. The "C" FA suffered a fractured pelvis.

ACC 121-9 America West Feb-01-99 Las Vegas
Airbus a320-232 Injuries: 1 serious, 134 uninjured.
At 0710 hours, a pax sustained a fractured hip when an America West a320-232 encountered turbulence in VMC while en route Tampa-Las Vegas. The accident occurred in cruise flight at FL310 about 1.5 hours after departing Tampa. The aircraft was not damaged. The PIC, FO, 3 FAs & 129 pax were not injured.

Statements from the 3 FAs & flight crew indicated the aircraft was in light to moderate turbulence. The seat belt sign was on and several PA system announcements had been made for the passengers to remain seated with their restraints fastened. A 70-year-old male passenger in seat 23c got up and began walking toward the aft lavatory. One cabin attendant told the passenger to return to his seat. The passenger, who has two artificial legs, ignored the instruction and continued to the aft galley area where he fell, fracturing his hip. The crew obtained medical advice by radio and the aircraft continued to its destination.

ACC 121-16 American May-13-98 Ft. Wayne, IN
Fokker F-28 MK100 Injuries: 1 serious, 38 uninjured.
At 0839 hours, an American Fokker F-28 MK100, enroute DCA-ORD, experienced moderate turbulence 20 miles east of Ft. Wayne, on descent through FL250. The #1 FA received a fractured ankle. The PIC, FO, #2 FA, and 35 pax were not injured. The 14 CFR part 121 flight was operating on an IFR flight plan. The flight continued to ORD, where it landed uneventfully at 0803.
The PIC reported they were experiencing "light chop" while descending through FL250 at 250 knots. He reported they were deviating south around a small cell when moderate turbulence was encountered. The PIC reported he called the FAs to tell them to take their seats. The #1 FA answered the call stating that they were already sitting down. The PIC stated that the #1 FA then came into the cockpit and informed him that she had fallen and hurt herself during the turbulence encounter. The PIC reported he instructed her to sit down and he coordinated with the #2 FA for her to assume the duties of the #1 FA for the remainder of the flight.
The #1 FA reported that the seatbelt sign had been turned on and she was completing her cabin check when it started getting "bumpy." she stated that she and the #2 FA sat down in pax seats near the back of the airplane. She stated the PIC called back on the interphone using two rings. She stated that she and the #2 FA remained seated until they heard the interphone ring a second time. The #1 FA reported she got up to answer the call. She reported, "I ended up flying through the air and then landing on my knee, and elbow with my ankles going every which way. I then got up to the back jumpseat and realized I was pretty shaken up and my head and ankles were hurting." she reported she then informed the PIC of the situation and that she needed medical attention.

SIGMET 20c was issued at 0355 EDT for Illinois and Indiana. The outlook for this SIGMET covered the area of the turbulence encounter and was valid from 0555 EDT until 0955 EDT. The outlook stated that thunderstorm activity was expected to slowly weaken during the period. A strong inflow of warm and moist air had ceased with a loss of the low-level jetstream and the southerly air mass over the region had begun to gradually stabilize. The upper system providing dymanic support for convection was moving northeastward across the upper Great Lakes into Canada.

SIGMET 1e was issued at 0555 EDT for Indiana and Michigan. The outlook for this SIGMET covered the area of the turbulence encounter and was valid from 0755 EDT until 1155 EDT. The outlook stated that widely scattered thunderstorm activity was expected to continue to slowly weaken during the rest of the morning. Both of these SIGMETs were included in the dispatch weather information provided to the flightcrew of n1400h prior to the flight.

ACC 121-18 Tower Air Apr-18-98 Atlantic Ocean, AO
Boeing 747-200 Injuries: 2 serious, 18 minor, 399 uninjured.
Preliminary: at 1437 eastern daylight time, a Tower Air 747-200 received minor damage when it encountered turbulence at 120 nautical miles east of kennebunkport, ME, at FL350. The 4 cockpit crewmembers, 11 FAs, and 384 pax were not injured. Two pax received serious injuries, while 3 FAs and 15 pax received minor injuries. VMC prevailed for the flight that departed Orly Field, Paris, France, at 0711.

According to interviews, the airplane was at FL350, at an indicated airspeed of mach .84 (287 kias), and an outside air temperature of -51 degrees celsius. The auto-throttles and “B” autopilot were engaged. The FO was the operating pilot. The flight crew had heard reports of light to moderate turbulence from preceding flights, and had experienced similar turbulence themselves. The seat belt sign was turned on about 5 to 10 minutes before the encounter, and meal service was taking place in the main cabin. The turbulence was described as lasting at 2 seconds, and consisted of 1 cycle, which was a nose pitch up followed by nose pitch down. The pilots reported an altitude deviation of 20 to 40 feet on the cockpit altimeters, and the auto-pilot and auto-throttles remained engaged. Unsecured personnel and objects in the aft cabin were thrown into the air, and then fell. One seat belt fitting which secured the belts of two seats (55d & 55e) to the seat frame was fractured. The overhead panels were dented in several places where persons or objects struck them.

AAC 121-19 Alaska Airlines Mar-04-98 Reno, NV

Boeing 737-242c Injuries: 1 serious, 5 minor, 110 uninjured.

At 1315 hours, an Alaska Airlines 737-242c enroute SEA-Las Vegas encountered severe clear air turbulence (CAT) in VMC at FL350 about 90 miles north-northeast of Reno. There was no damage to the aircraft. Of the 116 personnel onboard, 3 pax and 2 FAs received minor injuries, and 1 FA suffered a broken ankle. Due to the injuries, the flight diverted to Reno.

According to Alaska, en route conditions were smooth until the event. The PIC noted no turbulence, chop, etc., and there were no reports by other aircraft of any turbulence. After level off, the seat belt signs were turned off and the normal announcement made by the flight crew to keep the restraints fastened while seated. Normal service was in progress in the cabin at the time of the accident.

The FDR showed that vertical acceleration (nz) varied from +1.0g to +1.51g to -0.07g to +1.3g to +0.86g over a 6-second interval. The FDR also indicated stable atmospheric conditions (nz = 1.0g) at FL 350 during the several minutes prior to CAT onset.

ACC 121-20 Delta Jan-06-98 Orlando, FL

Boeing 757-232 Injuries: 1 serious, 188 uninjured.

At 1815 EST, a Delta 757-232 from ATL-Orlando had a pax injured when a coffee pot fell in his lap and spilled hot coffee on him in VMC turbulence. The aircraft was not damaged and the PIC, FO, 5 FAs, and 181 pax were not injured. One pax received serious injuries. The flight originated in ATL at 1723.

The PIC stated that the FO was flying the aircraft. After departure from Atlanta they were cleared to cruise at 29,000. They were between cloud layers and experienced continuous light turbulence. He left the seat belt sign on and had the cabin crew remain seated. They emerged from the turbulent conditions and were cleared to 27,000. There were no returns on radar within 60 miles of the aircraft and conditions were now smooth with some occasional light turbulence. He then told the cabin crew they could get up and begin cabin service.

The PIC sated that about 5 minutes after cabin service began, and after having been in smooth conditions for 10 minutes, the aircraft encountered at 4 to 5 seconds of instantaneous moderate turbulence. The aircraft was just east of Valdosta, Georgia at this time. There were no noticeable changes in altitude or airspeed. The remainder of the flight was smooth. He was later notified that coffee had spilled on a pax, causing injuries. He requested medical assistance to meet the flight on arrival in Orlando.

Two FAs stated that they were working with a beverage cart in the area of row 44, about 5 minutes after the PIC said they could get up. The aircraft encountered turbulence, went up, and then dropped. They and the cart were lifted off the floor. The full coffeepot fell from the top of the cart into the lap of a 7-year-old pax seated in seat 44d. The top came off the pot and coffee spilled into his lap causing burn injuries.

ACC 121-21 United Dec-28-97 Pacific Ocean, Of

Boeing 747-122 injuries: 1 serious, 188 uninjured.

At 2310 Japanese standard time (1410 UTC), a United 747-122 experienced severe turbulence about 950 miles east southeast of narita in VMC, bound for Honolulu. 374 pax, including 5 infants and 19 crewmembers were on board. 12 pax and one FA received serious injuries and one pax was a fatally injured. FAs and pax sustained an unknown number of minor injuries. Following the turbulence, the airplane returned to New Tokyo Airport for an uneventful landing. The flight was operating under FAR part 121.

ACC 121-24 American Oct-01-97 Cross City, FL

DC-9-82 Injuries: 1 serious, 3 minor, 91 uninjured.

At 2044 hours, an American DC-9-82 from Chicago experienced in-flight turbulence in cruise flight near Cross City, FL, in IMC. The airplane was not damaged and the PIC, commercial-rated FO, and 89 pax were not injured. One FA was seriously injured and two FAs and one pax sustained minor injuries.

According to the PIC, the flight was 110 nautical miles north of the pie vortac when they encountered a rapidly developing thunderstorm from below. As the cell appeared on radar, he checked the winds aloft on the fms and began a right turn. The flight then experienced no more than 1 second of moderate turbulence that injured all 3

FAs; there were no reported injuries to any pax. The flight continued and landed uneventfully at 24 minutes later. The seat belt sign was not illuminated at the time of the occurrence.

The FDR readout was coordinated with a National Track Analysis Program (NTAP) from the Jacksonville ARTCC, which depicts changes in heading, altitude, and ground speed. The FDR readout showed that at 15 seconds before the autopilot system was deactivated and continuing for at 12 seconds, the airplane began to roll right which increased to about an 11-degree right wing low attitude. During that time, both engine EPRs decreased and the indicated airspeed increased from 274 knots to a high of 278 knots and ended at 276 knots. Two seconds later the aircraft's vertical acceleration increased from a maximum of positive .95 gs to a maximum of 1.75 gs, and the aircraft rolled right at 15 degrees. One second later the autopilot system was deactivated, and one second after that the airplane rolled to the maximum of at 30 degrees right wing low, with a maximum of negative .28 gs. Vertical acceleration diminished and the airplane returned to cruise.

Review of weather surveillance radar from Tallahassee for the period of 2033.15 to 2042.55, showed a level 4 radar return located under and east of the flight track near the accident area. Due to the configuration of the radar at the time, the highest elevation for detection was 30,500 feet. The same radar returns for the period 2043.03, and 2052.44, revealed a radar return of level 3 to 6 along and to the east of the flight track. Additionally, at 2 minutes after the accident, or 2046 local, the Jacksonville ARTCC Weather Service Unit issued Center Weather Advisory 101. This indicated a cluster of level 5 thunderstorms and moderate rain with a diameter of 20 nautical miles with maximum tops to FL450. The center of which was located about 60 nautical miles west-southwest of Cross City, FL. That location, when plotted, was at 23 nautical miles west-southwest of the accident location.

ACC 121-25 American Sep-26-97 Long Island, NY
Airbus A-300 Injuries: 1 serious, 162 uninjured.

At 1615 hours, an American A-300 encountered turbulence while descending through FL260 over Long Island in VMC, enroute BOS-MIA. Two pilots, 7 FAs, and 153 pax were not injured. One pax received serious injuries.

The PIC's written statement said the seat belt sign was turned on when the flight departed FL330, 10 to 14 minutes before the accident. He further stated: "at FL260 [he] encountered moderate clear air turbulence. Turbulence lasted 15 to 20 seconds, smooth at FL 250 and below. Nor (sic) reported turbulence from NY center or other aircraft...FA notified me that a pax had injured his ankle." an American line foreman spoke to the PIC after the flight. In the foreman's statement he said: "they told me that they were at flight level 260 when they came on moderate turb [turbulence]. They had put out the speed brakes and pulled back the power. Shortly after the a/c [airplane] dropped. The FO [FO] kicked off the a/p [autopilot] and the a/c roll rolled to the left. They compensated for the problem and then flight went normal. The PIC also said that the seat belt sign was on..."

According to FA-3, the airplane was in a descent when they encountered turbulence. The FA stated that a cup of coffee had been handed to a pax and: "...he was on his way back to his seat, when turbulence hit. I held onto the wall and cart that was parked between the doors. The turbulence was severe enough that my feet left the ground. I made my way to the last row of seats and fastened the seat belt. The phone was ringing and I finally decided it was safe to get up to answer it...that was when I saw the man sitting at 4l with the #7 [FA-7]."

In a written statement, FA-7 stated that she had been in the rear left lavatory when the airplane encountered turbulence. She further stated: "I stayed in the lav until the end of the turbulence. I was trying to brace myself in the lav. I opened the door and saw the pax...on the floor holding his foot. He said his foot was completely dislocated from his ankle..."

A review of all statements revealed that the pax was observed on the floor, near the left rear emergency door (4l), after the accident. The pax had a torsional fracture of the ankle and had surgery at Mass General 3 days later.

ACC 121-27 Laker Airways Jul-25-97 Atlantic Ocean, AO
DC-10-30 Injuries: 1 serious, 3 minor, 320 uninjured.

At 1800, a Laker Airways DC-10-30, enroute Orlando-Scotland in VMC, was not damaged when it encountered turbulence over the Atlantic Ocean near JAX. The 3 pilots, 7 FAs & 310 pax were not injured; 3 FAs received minor injuries, and one FA received serious injuries.

In a written statement, the PIC said he briefed the FAs in-flight director (IFD) on the expected weather and westerly rerouting by air traffic control (ATC). The PIC stated that he suggested a 2 to 3 hour delay in the meal service due to extensive weather along the East Coast of the United States.

However, when the airplane reached 10,000 feet, the flight engineer called the cabin for a departure check. The cabin attendants stated that they then got up from their seats and prepared for a beverage service. In written statements and telephone interviews, several cabin attendants stated the call for departure check was their cue to leave their seats and begin service.

According to statements provided by the PIC and the FO, shortly after takeoff a deviation east of the intended course was requested from ATC due to thunderstorms. The request was denied due to arriving traffic already deviating in the area. ATC then approved a deviation west of course.

The FO stated: "northwest of [Craig] VOR, an opening was showing on radar that had sufficient size and distance for safe flight between cells. The radar also showed that it was clear on the other side of the thunderstorms. This appeared to be the best course at this time. The PIC ensured the seat belt sign was 'on' and told the flight engineer to make sure the cabin attendants were seated." In a written statement, the flight engineer stated he advised the cabin crew to ensure the pax and crew were seated, with seatbelts secure, approximately 3 minutes prior to the turbulence encounter.

According to all three members of the cockpit crew, the turbulence encountered was "moderate" and lasted 10 to 15 seconds. The FO described the encounter as "...intermittent light turbulence for up to 11 seconds; moderate chop for 4 to 5 seconds." The IFD stated: "...the cockpit called to advise of moderate turbulence and to sit. When I picked up the PA to let the [cabin attendants] know, it was too late. The plane went up and down a couple of times, heaving us up in the air in the [forward] galley."

In written statements, several FA said they were advised to take their seats after the turbulence began. The FAs in the aft galley stated they were thrown up and down and that liquor bottles, cans, and beverage carts were bounced about and on top of them. One cabin attendant described the aft portion of the cabin as "a total disaster; there was alcohol 6 inches deep floating by the R4 door and in the galley. There were broken bottles, punctured soda cans spraying and the metal bins were folded like accordions. Everything that came out of the bins was on the floor blocking the entrance to the galley." the injured cabin attendants were positioned in the aft section.

The PIC stated that after receiving an assessment of the injuries on board, and consulting with Laker dispatch, Bangor, ME was chosen as the landing site to seek medical attention. Four FAs were treated at the hospital. One cabin attendant returned to the airplane, and the airplane continued to Prestwick, Scotland.

In a telephone interview conducted august 11, 1997, a cabin attendant stationed in the forward portion of the cabin (l2 door) stated the flight engineer came out of the cockpit to advise her that a turbulence encounter was anticipated in approximately 5 minutes. She stated the flight engineer directed her to secure her galley and to advise the remainder of the cabin crew.

The cabin attendant stated she immediately began to secure her galley. She said the galley can be secured in approximately 10 minutes. The cabin attendant stated she had secured "...at 30 percent..." of her galley when she stopped her work, picked up the interphone, and advised the mid galley of the forecast turbulence and to secure the galley. She replaced the interphone and returned to secure her assigned galley. The FA did not advise the aft galley. The FA said the IFD appeared at her station shortly after she returned to her work. She advised the IFD of the forecast turbulence and he responded, "I know, I know." When questioned why she failed to contact the aft galley, she stated: "I don't remember...there was such a miscommunication at this time. Everything was coming from the flight engineer, not the PIC. I can only do one thing at a time. I didn't think to ring the one in the back. I only spoke to the mid. I didn't have time to call the one in the back. I figured the in-flight director would handle the one in the back."

Additional information; after discussion of the chronology of events and the procedures used on the accident flight, the director of operations for Laker Airways revised and published changes to the general operations manual, the cabin attendant training manual, and the in-flight service manual. The revisions were approved and accepted by the FAA principal operations inspector for Laker Airways on august 14, 1998.

The published changes included the following: turbulence encounters: when weather forecasts or existing conditions indicate a possibility of turbulence the crew will be thoroughly briefed by the PIC...if turbulence is expected during climb or departure, the departure check announcement should be briefed and include the phrase "departure check, cabin attendants remain seated until further advised." when clear of all clouds and expected turbulence the PIC will then announce that the FAs may resume service. For turbulence encounters in flight, a PA announcement is to be made advising the FAs to "suspend service until further advised." at this point, all service will be immediately suspended and cabin attendants will immediately return to their stations and fasten their seatbelts until advised by the PIC to "resume service."

ACC 121-33 TWA Jan-28-97 Cape Girardeau, MO
DC-9-51 Injuries: 1 serious, 1 minor, 110 uninjured.
At 0853 hours, a TWA DC-9-51 experienced severe clear air turbulence over Cape Girardeau during initial descent into STL. One FA was seriously injured, a second FA received minor injuries. The PIC, FO, a third FA, and 107 pax were not injured. The airplane was not damaged. The flight originated from MSY at 0751.

The FO, who was flying, reported that they were informed to expect FL240 over Cape Girardeau instead of the usual FL280 because it was "bumpy." he stated the seat belt sign was turned on during the descent to FL240. He reported they were then cleared down to FL230. He stated the ride was smooth at FL230 so the seat belt sign was turned off. He reported that after a few minutes they encountered turbulence at which time they turned the seat belt sign back on and made a PA announcement for the pax to be seated. He stated that it was at this time that the severe turbulence was encountered. The flight crew notified the Kansas City ARTCC of the turbulence and requested a lower altitude. The PIC reported they checked with the FAs to see if anyone was injured. They were informed that one pax and two FAs had sustained injuries. An emergency was declared and the flight was cleared to STL.

The PIC reported that the turbulence was "intense and the duration was approximately 30 seconds." he reported that they had no warning prior to the encounter and they were in clear air.

Injury information: two of the three FAs were injured. FA L1 received bruised ribs. FA C1 received a broken left clavicle, fractured left ribs, strained neck muscles, and bruising.

FA L1 reported she was finishing up service when the seat belt sign came on. A pax came out of the lavatory and it became "moderately turbulent." she reported that the seats were full so she had the pax get down on the floor and she held on to the pax. She reported the turbulence quit at which time she and the pax got up. On the way to the pax seat she heard someone say "sit down." she reported they once again experienced turbulence and she pushed the pax onto the floor and yelled for other pax to hold her down. She stated that she "flew up and hit the ceiling. I came down and hit my face on the seat, then flew back up and hit the ceiling and came down on the back of a seat with my left side." She reported she landed on the floor in between a row of seats. She got up, checked on the pax she pushed to the floor and took her back to her seat. She then walked through the cabin checking on pax and saw the C1 FA on the floor in the back galley. She reported he was complaining of shoulder pain. She made another seat belt PA announcement, called the cockpit, got in her jumpseat, and aided the C1 FA. When she was told it was ok to get up, she walked through the cabin to check on pax, and went to the cockpit to brief the flight crew.

The R1 FA who was in the rear galley reported the seat belt sign was off when one pax got up to use the lavatory and another got up to look at the magazine rack. He reported the pax came out of the lavatory and "gentle turbulence" was experienced. He reported the L1 FA held onto the pax and had her get on the floor. He reported he had the pax at the magazine rack sit down and secure his seat belt. He reported that the seat belt sign came on and he made a PA announcement for everyone to check and fasten their restraints. He reported that the turbulence stopped for about a minute. The L1 FA walked the pax back toward her seat and he went about his duties in the rear galley. He reported, "then it hit, I went flying to the ceiling, down to the floor on my left side at which time I heard something snap in my shoulder. ... Then I went up in the air again, hit the ceiling and came down again on my left side." he reported he was lying on the floor when the turbulence stopped and the L1 FA came back and got in her jumpseat. He got up into his jumpseat but was unable to put his restraint on because of the shoulder pain. He reported he felt sick and he told the L1 FA that he had to get back on the floor before he passed out. He reported he got on his knees and crawled to get behind row 24-d/e where he laid down and stayed for the remainder of the flight, aided by the other FAs.

The R1 FA, who was not injured, reported he was in the front galley when they hit some "unexpected turbulence" which he described as "very severe." he continued to report, "it lasted about 5 to 10 seconds and stopped. My feet left the floor as I tried to brace myself. A few seconds later we hit very severe turbulence again. This time it lasted a little bit longer and was a little more intense. My feet left the ground again and I hit my head on the ceiling." he reported he got to his jumpseat and after a few minutes received a call from the L1 FA telling him they would assist the pax once it was safe to get up. The L1 FA also informed him of the injured C1 FA. He reported that once it was safe he went to the back of the airplane and aided the C1 FA.

Meteorological conditions: at 0755 CDT (1355z), SIGMET victor 2 was issued which was valid until 1155 CDT (1755z). The SIGMET was for portions of Missouri, Illinois, Indiana, Kentucky, Ohio, Pennsylvania, and West Virginia. The area listed in the SIGMET was from Erie, PA; to slate run, PA; to Johnstown, PA; to London, KY; to Walnut Ridge, AR; to Springfield, MO; to Ft. Wayne, IN; to Erie, PA. The SIGMET called for moderate occasional severe turbulence between FL240 and FL350 due to windshear involving upper level jetstream. These conditions were reported by a number of aircraft. Conditions were expected to continue beyond 1155 CDT.

At 0930 CDT (1530z), SIGMET victor 3 was issued for the same area as victor 2 with the altitude changed to between FL210 and FL350. This SIGMET added the comment that injuries were reported by a DC-9 at FL210-FL220, 50 southeast of Farmington, MO. Conditions were expected to continue beyond 1330 CDT.

Numerous PIREPs were received by ATC regarding moderate to severe turbulence over Springfield, MO; Evansville, in; St. Louis, MO; and throughout Southern Illinois, both prior to and around the time of this incident. (see attached PIREPs

Communications: TWA 374 was in contact with the MKC ARTCC, sector 54 radar position controller when the turbulence was encountered. The TWA flight crew checked in with the controller at 0849:37 as being level at FL230. At 0852:41, TWA 374 reported "...its real bumpy here can we have lower please." at 0853:03, the controller cleared them to descend and maintain FL130 and to expedite descent through FL210. TWA 374 acknowledged the clearance.

At 0853:36, TWA 374 reported "Kansas City we just encountered uh severe turbulence and uh we're descending now through flight level two two zero for one three thousand." at 0854:25, the controller advised TWA 602, which was about two minutes behind TWA 374, of the severe turbulence. At 0855:20, after several inquiries about the turbulence from other aircraft in the area, the controller made a broadcast over his frequency "all might want to put your restraints on."

At 0856:32, TWA 374 radioed "...be advised we were ninety miles south of St. Louis on the one five five radial when we hit that severe turbulence which was uh intense enough to uh make it difficult to read the instruments and also it threw a lot of stuff around inside the cockpit. I wouldn't recommend that you send anybody through there above flight level one eight zero." the controller asked TWA 374 if they wanted any emergency equipment waiting for them in STL. At 0857:01, TWA 374 replied "that's negative I just want you to know that it's uh clear air there but it's very uh very rough it may dissipate momentarily but it's very rough right now."

At 0857:12, TWA 602 transmitted "...we're just uh fifteen miles to the north of Cape Girardeau we just got a real good jolt there at two one zero we'd like lower." at 0859:23, TWA 374 declared an emergency and requested that equipment be standing by in STL because they had injured pax and FAs. TWA 374 was then cleared to contact St. Louis approach control.

At 0901:57, TWA 602 transmitted "you might want to pass this information back to the uh flights behind us you know it was smooth for us at twenty one and we hit a jolt that was out of the unexpected that was hard enough that it put the FAs head through the uh uh upper bulkhead and uh like I said it was just one jolt and its been smooth everywhere else." at 0903:39, TWA 602 transmitted that they were going to need the paramedics in St. Louis.

Flight recorders: the CVR was not retained for readout. The FDR was retained but an unsuccessful attempt to readout the data was made at TWA's facility on January 31, 1997. The recorder was then taken to the NTSB recorder laboratory where a readout was performed on february 11, 1997. The data indicates that the changes in vertical acceleration during the most severe turbulence encounter by TWA 374 ranged from +2.5g's to -.79g's.

ACC 121-34 American Jan-07-97 Atlantic Ocean, AO

Airbus a300B4-605r injuries: 1 serious, 5 minor, 259 uninjured.

At 0834, an American a300B4-605r encountered turbulence in VMC over the Atlantic Ocean. One FA received serious injuries, 3 FAs received minor injuries, and 2 pax received minor injuries. The remaining 252 pax and 5 crewmembers were not injured. The airplane received minor damage. The flight had departed PHL for SJU at 0800.

The flight was cruising at FL330, about 30 miles south of Champs Intersection, when it encountered the turbulence. The seatbelt sign was illuminated. The injured FAs were working in the forward and aft galleys, in preparation for cabin service. Both pax were seated in the rear of the airplane and had their seatbelts unfastened at the time. A cart in the aft galley was thrown into the air and hit the overhead ceiling.

The PIC was notified of the injuries and diverted to JFK for an uneventful landing. After taxiing to the gate where the pax were deplaned through the jetway. One pax and the two FAs who were working in the aft galley were taken to local hospitals where they were treated and released. One FA was found to have a fractured ankle. There were no SIGMETs in effect for turbulence.

The FDR showed 2 pulses 8 seconds apart. Each pulse had a max value of +1.6 gs & minimum of +0.25 gs, as measured on the vertical axis of the airplane.

ACC 121-37 Air Wisconsin (United Express) Dec-20-96 Denver
BAE 146-200a Injuries: 2 serious, 14 uninjured.
At 1750, an Air Wisconsin BAE 146-200a, operating as United Express flight 684, sustained no damage when it encountered severe turbulence in VMC 30 miles northeast of Denver. There were no injuries to the 2 pilots & 12 pax, but 2 FAs sustained serious injuries. The flight originated at Eagle, Colorado, at 1730.
The flight had been cleared to descend from FL190 to 13,000 on the Thompson one arrival into Denver. The PIC stated that they encountered "one sharp clear air turbulence jolt. Duration was approximately 20 to 30 seconds with moderate turbulence the remainder." the airplane landed without further incident and as it was being taxied to the gate, a pax contacted the cockpit crew via interphone to advise that both FAs had been injured.

According to the FO's statement, the airplane was passing 14,000 at 240 knots when speed increased to 270 knots, followed by a severe downdraft. The airplane was "displaced only in pitch, not roll." the turbulence encounter lasted approximately 10 to 15 seconds, followed thereafter by only occasional light turbulence. A pax then notified the crew via intercom that both FAs had been injured. The airplane landed at Denver at 1805 and was met by paramedics who transported the injured FAs to a hospital.
The FA most seriously injured sustained a fractured pelvis, fractured collarbone, & 2 fractured ribs. In her written statement, she said it had been a smooth flight. She was walking forward to complete the pax landing check when the airplane hit turbulence and she was thrown off her feet, striking the ceiling.
The other FA fractured her ankle. In her written statement, she said the previous flight to Eagle had been routine with no significant wx and very little turbulence. As the airplane began its descent into Denver, the seatbelt sign was illuminated as she and the other FA made their pre-landing checks. She stood to give the pax instructions over the PA system while the other FA walked through the cabin. She did not recall the turbulence encounter.

According to the Denver ARTCC and TRACON, no turbulence warnings were issued to United Express flight 684 because they had not received any turbulence reports from other inbound flights.
The FDR showed "the aircraft was descending through 14,000 feet when significant excursions in the aircraft's vertical and lateral acceleration occurred. During this time the IAS increased from 272 to 284 knots. Four seconds after the disruptions began the autopilot disconnected. Immediately thereafter the aircraft's pitch increased about 8 degrees and the vertical acceleration spiked sharply going from a minimum 0f -.75 g's to a maximum of 2.37 g's in about one second. These events were accompanied by a right roll of approximately 6 degrees, yet during this time the aircraft yawed to the left. The airbrake was applied...and the aircraft began to decelerate."

ACC 121-39 USAir Aug-29-96 Chattanooga, TN
Boeing 737-300 injuries: 3 serious, 1 minor, 84 uninjured.
At 1553, a USAir 737-300, from Tampa to ind, encountered severe turbulence in VMC 45 miles south of the Chattanooga VOR, while in cruise at FL350. The PIC, FO, 3 FAs, and 79 pax were not injured. Three pax sustained serious injuries and one pax sustained minor injuries. The airplane sustained minor damage. The flight originated from Tampa at 1435. The PIC diverted to Chattanooga.
The PIC stated he was in cruise at FL350 in VMC at 45 miles south of Chattanooga. The wx radar was on the 80-mile range with no wx present. The airplane encountered severe turbulence. A FA notified him that they had sustained injuries in the cabin area. He contacted ATC after assessing the situation, and requested to divert to Chattanooga, which was approved.
The FDR showed the flight was at 35,000 MSL when it was subjected to severe vertical acceleration oscillations. The vertical acceleration peaked at 1.81 g's, -1.38 g's, 1.99 g's, and continued to oscillate for 28 seconds.

Review of geostationary operational environmental satellite (goes) 8 data shows an area of active convection from 15 to 40 nautical miles east of (gqo) choo choo VOR. The goes 8 images show no significant convection in the area 45 miles south of gqo.

AC I-40 Frontier Airlines Jun-22-96 Granite, CO
Boeing 737-201 Injuries: 1 serious, 2 minor, 95 uninjured.
At 1545 hours, a Frontier Airlines 737-201 was not damaged when it encountered severe turbulence in VMC on descent over granite, CO. One pax received serious injuries, and one pax and two FAs received minor injuries. There were no injuries to the PIC and FO, the other FA or 91 pax. The flight originated in Albuquerque at 1505.

According to the PIC, he had begun the descent from FL290 into Denver and had been forewarned of reported turbulence. The "fasten restraints" sign was turned on, and FAs were instructed to be seated and to fasten their restraints. An elderly woman got up and walked towards the aft lavatory. The airplane began to encounter light turbulence and a FA attempted to seat the pax in a FA jump seat. Before her seat belt could be fastened, the airplane encountered severe turbulence and the pax sustained a serious back injury. The FA struck her head against the cabin ceiling, then struck her hip against the galley. At that time, the airplane was at FL240. Written statements were submitted by the three cabin crewmembers that corroborated the PIC's report.

The FDR showed the airplane was on a magnetic heading of 325, at 280 knots, and in a shallow descent from 29,000 when it had "violent vertical acceleration oscillations" that lasted 150 seconds. Oscillation magnitudes ranged from +2.0 g's to -0.5 g's.

ACC 121-41 American Apr-07-96 Atlantic Ocean, AO
Boeing 757-200 injuries: 1 serious, 193 uninjured.
At 2000 hours, an American 757-223, enroute JFK-Caracas, encountered severe turbulence while in cruise at 31,000 MSL 300 miles west southwest of Bermuda. The airplane sustained no damage. The 2 pilots, 4 FAs and 187 pax reported no injuries. One FA received a serious injury. The airplane diverted to Bermuda.

The pilots reported that the flight had been uneventful and smooth, until the unexpected encounter with severe turbulence. Company personnel indicated that during the brief encounter with turbulence, one of the aisle carts became airborne and struck a FA's leg when it came back down to the floor. The FA received a leg fracture. There were no other reported injuries. There was no forecast for turbulence for the planned route of flight.

ACC 121-43 American Jan-17-96 Atlantic Ocean
Airbus a300B4-605r injuries: 3 serious, 17 minor, 248 uninjured.
At 1438, an American a300B4-605r, en route MIA-SJU in IMC, encountered turbulence in an enroute descent from FL350 over the Atlantic Ocean near Cat Island, Bahamas. The aircraft received minor damage. The PIC, FO, 7 FAs, and 239 pax were not injured; 17 pax reported minor injuries and 3 pax reported serious injuries.
The PIC, who was flying, said that after departing Miami they climbed to FL330, where they encountered light to occasional moderate turbulence. He turned on the pax seat belt sign and it remained on until after the accident. They received information from ATC that the ride was reported to be better at 27,000 and 35,000. They asked for and received clearance to FL270.

At FL270, they encountered turbulence and observed clouds below. They asked for and received clearance to 35,000. Upon reaching FL350 they found the turbulence was worse. He then requested and received clearance back to 33,000. As they began the descent they encountered severe turbulence. After the aircraft was brought under control he advised ATC of the encounter with turbulence and received an injury report from FAs. Based on the information he received from the FAs and doctors who were treating the injured, he elected to continue to san juan and avoid possible further injury by flying back through the area of turbulence.

The FO stated later that when they reached FL350, just before the turbulence encounter, they were in and out of the jagged tops of the clouds. The winds were shifting from the west to northwest. There was no wx showing on radar. As they began the descent to FL330, they entered the clouds and were in the clouds at the time of the accident, with the autopilot and autothrottles on. Airspeed increased to .81 mach due to fluctuations from the turbulence. During the turbulence the autopilot disconnected. There was nothing remarkable about the weather information they received before takeoff & ATC provided no SIGMETs.

The FAs stated that after departure it was bumpy and they delayed meal service. The seat belt sign was on & several announcements were made in English and Spanish for pax to remain seated with restraints fastened. The FAs remained seated with their restraints on. They stated that during the severe turbulence, several pax did not have their restraints fastened or were not in their seats, & they struck the overhead areas and were injured.

Meteorological information: satellite images showed an area of clouds existed in the area of the turbulence encounter at the time, with thunderstorms in the cloud area and significant turbulence between 25,000 and 36,000 feet.
The national weather service had issued SIGMET echo 1 at 1236. The SIGMET stated that satellite observations show an area of active thunderstorms with tops to 38,000 in the area of the accident. The area was moving north at 5-10 knots and was intensifying. The SIGMET was in effect until 1640. The flightcrew stated they did not receive this SIGMET in the wx information from American before takeoff. They further stated they did not hear it

broadcast on the normal ATC frequencies and did not listen to the weather information frequencies where it was being broadcast.

American produces a variety of tailored aviation forecast and advisory products under the FAA enhanced weather information system program. national weather service products are not forwarded to flight crews directly, but are evaluated during the preparation of the American weather products and are available to flight crews through the computer system. Weather information that was supplied to the flight crew before departure forecast a weak upper level cyclonic circulation producing cloudiness/scattered showers across southern Bahamas. isolated thunderstorms possible within showers discussed above. No thunderstorm sigmec issued. No CAT sigmec issued. CAT indicator 0 (smooth).

Flight recorders: the CVR was not retained for readout, as the accident event was no longer present on the CVR at the time of arrival in san juan. The FDR showed that at the time of the turbulence encounter the aircraft was descending through 34,500 MSL, on a heading of 110 degrees, at a calibrated airspeed of 290 knots. Vertical acceleration increased to 2.088 g's, decreased to -1.032 g's, and then increased to 1.788 g's.

ACC 121-44 Mahalo Air Dec-30-95 Honolulu

Atr 42-300 injuries: 1 serious, 23 uninjured.

At 0843 hours, a FA onboard a Mahalo Airlines ATR-42 from Lihue to HNL sustained a fractured ankle in turbulence while on approach to HNL in VMC. The aircraft was not damaged. The FA sustained serious injuries; the 21 pax and 2 pilots were not injured.

The PIC & the injured FA both said that the PIC anticipated moderate turbulence for the flight due to frontal system activity over Hawaii. The PIC briefed the FA on the expected turbulence for the entire flight and kept the seat belt sign on continuously. Turbulence was encountered for the majority of the flight.

On radar vectors for the lda runway 26l final approach to Honolulu, the aircraft was descended to 7,000 and was heading toward the only clear area between cells shown on both the aircraft and approach control radars. No turbulence had been encountered for several minutes and the FA elected to do a seatbelt compliance check on the pax. The PIC said 3 strong jolts were encountered accompanied by altitude excursions as the attendant was returning to her seat in the rear of the aircraft. The FA was bounced off the ceiling twice and sustained a displaced fracture of the left ankle.

ACC 121-47 United Nov-01-95 Pacific Ocean, PO

Boeing 747-122 injuries: 1 serious, 300 uninjured.

At 1515 UTC (night), one pax was seriously injured on a United 747-122 during a moderate turbulence encounter over the Pacific Ocean from Tokyo to HNL. The accident occurred in International Airspace between latitudes 28 - 33 degrees north and at longitude 173 degrees west, while the aircraft was in cruise at FL350 (5 hours from Tokyo & 2 hours from HNL). The aircraft was not damaged. The remaining 279 pax, 18 FAs, and flight deck crew of three were not injured.

Reports from the flight crew to United's flight safety dept stated that the aircraft was in clear air. Convective activity associated with a front was visible in the distance ahead and on radar. The flight crew characterized the radar return as a solid yellow band across their flight course with an area of green return to the south. The flight crew elected to alter course to the south and follow a preceding Japan Airlines flight through the area of lighter returns. In response to a report of moderate turbulence from the preceding aircraft, the flight crew turned on the fasten seat belt sign at 1500 hours. 10 minutes later, because of turbulence, FAs were instructed to take their seats.

While the FAs were seated and the flight was encountering light turbulence, a female pax in the upper deck lounge left her seat to go to the lavatory. According to the FAs and other pax witnesses, the FAs called to the English-speaking, American pax to remain seated, but she declined and continued to the lavatory. While returning to her seat, moderate turbulence was encountered and the pax fell in the aisle. The pax complained of pain in her right leg and FAs, assisted by the second officer, immobilized her leg prior to helping her to a nearby seat. Two doctors anboard talked with the pax and paramedic personnel met the flight in HNL. Subsequent examination revealed multiple fractures of the pax's right leg.

ACC 121-48 United Oct-17-95 Pacific Ocean, PO

Boeing 747-422 Injuries: 1 serious, 5 minor, 331 uninjured.

At 0944 UTC (night), 6 pax were injured during severe turbulence over the pacific onboard a United 747-422 from Hong Kong to SFO. The accident occurred in international waters near latitude 40 degrees north, longitude 152 degrees east, while the aircraft was in cruise at flight level FL330. The aircraft was not damaged. One pax sustained serious injuries and five additional pax incurred minor injuries. The other 303 pax, 18 FAs, & 4 pilots were not injured.

The original dispatch package given to the flight crew prior to departure included wx data and forecasts of moderate turbulence along the aircraft's planned track from 151 to 162 degrees east longitude. PIREPs available at the time of departure consistently reported smooth conditions in the area of the forecast turbulence.

According to pilot & FA statements, the aircraft was in level cruise at FL330 in clear air above a cirrus cloud deck. The crew saw no convective activity ahead either visually or on radar. In the process of preparing for a position report to ATC, the flight crew overheard a Delta flight, which was ahead of them on their assigned track at FL350, reporting moderate to severe turbulence. The PIC decided to secure the cabin as a precaution. The purser was notified of the decision and the PIC was in the process of reaching for the seat belt sign when the turbulence was encountered.

The crew described the encounter as "one sudden heavy jolt," accompanied by airspeed and altitude excursions of plus and minus 20 knots and 200 feet from the respective cruise target values. Moderate turbulence then continued for at 20 minutes thereafter.

All of the injured pax were located aft of row 50, with the majority aft of row 58. None of the injured were secured by restraints. The 62-year-old female pax who was seriously injured was in the 5r lavatory at the rear of the aircraft at the time of the encounter. Her injuries consisted of compression fractures of several lumbar vertebrae.

ACC 121-49 Northwest Aug-04-95 a Detroit

Boeing 757 Injuries: 1 serious; 127 uninjured.

At 2248, a Northwest 757, from SFO, encountered sudden, moderate, turbulence at FL270. One pax received serious injuries as she exited the lavatory when the turbulence was encountered. The 7-person crew & 120 pax reported no injuries.

According to the pilot's written statement, they had descended from FL410 and had just leveled off at FL270, about 25 nautical miles east of Grand Rapids, when it encountered the sudden, moderate turbulence. He said the airplane's weather radar was on the 80 mile scan and showed no weather. He said the seat belt sign had been put on and an announcement was made advising the pax to expect "bumps" on the approach into Detroit. The company's director of flight safety said the seat belt sign was "...turned on at the top of [the] descent which would have been about 5 minutes... Prior to the encounter with the turbulence."

The director said the FA's reports concerning the incident did not "...indicate that anyone saw the lady enter the lavatory." he said it is presumed that the pax was in the lavatory when the seat belt sign was turned on. The lavatories are equipped with a public address speaker, FA call button, and a sign that reads: "return to seat" when the seat belt sign is illuminated in the cabin.

The FO said the flight was initially cleared to FL230 but, according to her statement, the FAA controller changed the clearance to FL270 because the flight would have "...the best ride..." at that altitude. According to the airline's dispatch/meteorology department weather data, the area around flight 52 had been experiencing 3/10's coverage of level three and four thunderstorms.

ACC 121-53 Delta Mar-16-95 Alma, GA

Boeing 727-200 injuries: 1 serious, 5 minor, 132 uninjured.

At 1435 hours, a Delta 727-200 encountered severe clear air turbulence at 37,000 feet in VMC, enroute Nassau-Atlanta. The aircraft was not damaged. Four flight crewmembers and 132 pax were not injured; 7 pax and one FA received minor or serious injuries. The flight departed Nassau at 1334 hours.

According to the flight crew, they had completed two previous flights that day without incident. They departed Nassau (NAS) and experienced light "chop" at FL330 and requested a higher altitude of 37,000 feet for this flight. The FO stated that they had experienced steady turbulence until reaching an altitude of 35,000 feet. After passing this altitude the turbulence subsided to "light chop". The fasten seat belt light was on, due to the turbulence they had previously experienced.

Atlanta ARTCC center informed the crew of a PIREP from a 737 that had experienced severe turbulence at FL330 well south west of their position. The FO was flying the aircraft. He stated that they were in VMC at FL370. The undercast below the aircraft was a fairly uniform composition. No towering cumulus clouds, or other build-ups were noted. The weather radar on board the aircraft did not indicate any possible hazards for their route into ATL.

Between 1435:31.42 and 1435:31.45, without warning, the airplane rolled 52.2 degrees right and 58.9 degrees left. The vertical acceleration reached a maximum of 1.93 "g" and a minimum vertical acceleration of -0.80 "g" within the same time interval. The PIC retarded the throttles and the FO grasped the yoke with both hands, as the aircraft descended into a haze layer. Heavy buffeting continued until the aircraft descended below the haze layer. The wings were then near level attitude. The PIC advanced the throttles as the FO brought the nose of the aircraft back up level with the horizon and disengaged the autopilot. During the entire sequence, the aircraft lost approximately 1,500 feet of altitude.

After the flight crew regained control of the airplane, the cabin crew reported that several pax and one FA were injured. The medical examinations disclosed that the pax in seat number 32b was seriously injured, and did not have his seat belt fastened when the aircraft encountered the turbulence.

ACC 121-54 Delta Jan-06-95 Monroe, LA
MD-88 injuries: 1 serious, 69 uninjured.

At 0920 hours, a Delta MD-88 from Monroe, LA, encountered turbulence on climbout 30 miles east of Monroe in IMC. The airplane was not damaged. The PIC, FO, 2 FAs, and 66 pax were not injured. One FA sustained a serious injury. The diverted to Jackson, Mississippi.

The PIC said the airplane encountered light to moderate turbulence on climb-out. The cabin seatbelt signs were illuminated and the FAs were briefed to remain seated. The airplane weather avoidance radar was on and no significant weather was present on the radar screen. An overhead compartment had opened up in the cabin area, and a FA got up to secure it. The airplane encountered a couple of seconds of intense moderate turbulence, and the FA collided with the cabin overhead panels.

The FDR showed the airplane was climbing through 9,187 feet when it was subjected to intense vertical acceleration for at 2 1/2 seconds. The "g" value peaked at 1.771 to a minimum value of -0.276 for a total of 1.9 "g" excursion.

ACC 121-55 USAir Sep-19-94 Atlantic Ocean
Boeing 737-400 injuries: 1 serious, 131 uninjured.

At 1839 hours a USAir 737-400 experienced turbulence during descent over the Atlantic Ocean while operating from charlotte to West Palm Beach in IMC. The airplane was not damaged. The PIC, FO, 3 FAs, and 126 pax were not injured. One FA received serious injuries.

One FA was standing in the rear galley when the airplane experienced one jolt of turbulence. She was evacuated from the airplane upon arrival in West Palm Beach. Examination revealed she had a fractured lower back vertebra.

The crew stated they were established in descent with the weather avoidance radar on and the airplane encountered one jolt of turbulence. They stated that no echoes were observed on the radar. The NTSB meteorology division conducted a factual weather report of the environmental conditions and the airplane was placed in an area of developing convection cells that would not necessarily show up on airborne weather radar

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ACC 121-57 ValuJet Jul-05-94 Valdosta, GA
DC-9-32 injuries: 1 serious, 87 uninjured.

At 0810 hours, a ValuJet DC-9-32 encountered turbulence during climb to cruise over Valdosta, Georgia, in IMC from ATL to Orlando. The airplane was not damaged and one FA received serious injuries. The rest of the crew and pax received no injuries.

The crew reported that during climb at FL180 they encountered "moderate chop" and then illuminated the seatbelt sign and made an announcement for the pax to remain seated. They also instructed the FAs that they could begin cabin service. One FA in the rear galley suffered multiple fractures of the right lower leg. The flight continued to Orlando, where the FA was evacuated to a hospital.

A review of the available meteorological data showed no evidence of thunderstorms or convective activity. The FDR readout indicated a "g" excursion of minus .4 to plus 2.4 "gs".

ACC 121-59 United Feb-12-94 Pacific Ocean, PO
Boeing 747-400 injuries: 1 serious, 408 uninjured.
At 1345 UTC (night), a United 747-400 from LAX to auckland encountered clear air turbulence at FL350 over the Pacific Ocean at a position w 157.00 by s 010.03.4. During the encounter, a FA fell, sustaining a fractured right clavicle. The aircraft was not damaged. One FA sustained serious injuries; the remaining 408 pax and crewmembers were not injured. The flight originated at Los Angeles, California on the day of the mishap at 0626 PST as a nonstop flight to New Zealand.

According to United, the aircraft was on an authorized off-course deviation, approaching megog intersection, to circumvent some convective activity that had been identified on radar. As a precaution, the "fasten seatbelt" light was illuminated and the PIC told the chief purser to advise the other FAs of possible turbulence and to be seated. 10 minutes later at Megog Intersection, the aircraft encountered 3 to 5 seconds of what the PIC described as moderate-to-severe turbulence. The weather radar was on at the time of the actual encounter; however, there were no weather returns showing on the scope. During the turbulence, one FA who did not get the prewarning was answering a pax call, and was not seated. Pax reports indicate that, at the onset the upset, the FA left the floor and came back down hard on her shoulder and side. It was later determined that the FA suffered a hairline fracture of the right clavicle.

ACC 121-61 Delta Sep-15-93 Atlanta
Boeing 757-232 Injuries: 1 serious, 187 uninjured.
At 2145 a Delta 757-232 encountered moderate turbulence climbing through FL140 in VMC 10 miles east of Atlanta. One FA in the rear of the airplane was injured. The airplane was not damaged and one of the 188 persons on board was injured.

According to the PIC, ATC cleared the flight to 14,000 and the seat belt sign was turned off as the airplane climbed through 10,000. The FAs reported that the flight was normal as they started pax service. As the flight climbed, the pilots observed a thin layer of clouds along their route of flight. They continued the climb through the layer of clouds; they also observed, on the airborne weather radar system, isolated cumulonimbus (cbs) clouds 5 miles northeast of the flight path. At FL130, the flight encountered what the PIC described as moderate turbulence; the seat belt sign was immediately turned on. The flight broke out of the cloud layer at 14,500; the pilot deviated south of the cbs and continued the flight into columbia, South Carolina.

After the turbulence, the PIC was informed of the injury sustained by the FA. The flight landed without further incident. Additionally, the flight crew reported that turbulent conditions were encountered during their previous flight, into Atlanta, about two hours before flight 240's departure.

ACC 121-64 Simmons (American Eagle) Jun-04-93 Chicago
ATR 72-212 injuries: 1 serious, 67 uninjured.
five minutes and 10 miles southeast of O'Hare, an American Eagle ATR-42 encountered "severe vertical turbulence during climb." one FA sustained a fractured ankle during a fall. The flight returned to O'Hare for an uneventful landing. The aircraft, destined for Champaign, Illinois, was undamaged.

ACC 121-66 Henson Aviation (USAir Express) Mar-23-93 Jacksonville
DHC-8-102 injuries: 1 serious, 21 uninjured.
38 mi from the destination arpt, the PIC notified the FA to be seated due to possible turbulence encounter. After completing the approach checklist, the FA was given the signal to perform the final cabin check. 9 mi from the arpt, the flight encountered "a single strong windshear" which caused the FA to be thrown against the ceiling & then to the floor. At the time of the occurrence, the airplane was operating within a weak level I wx radar return, within 6 mi of a level ii return, and within 9 mi of a very strong level iv return. The operator's flt ops manual states that the PIC will advise the FA as to whether or not he/she should be seated with the seat belt fastened. In addition, neither the

flt ops manual nor the FA manual gave any instructions as to when the FA should resume his/her duties after being told to be seated, nor was the PIC instructed to notify the FA to resume his/her duties.

ACC 121-69 Connie Kalitta (American Int'l) Dec-09-92 Denver
DC-8-52 injuries: 3 uninjured.
While in cruise flight at flight level 310, 20 miles west of Denver, Colorado, the cargo flight encountered severe clear air turbulence that caused major fluctuations in speed and oscillations in both pitch and roll. During these departures from controlled flight, the number one engine and 19 feet of the leading edge of the left wing separated from the aircraft. In addition, the number four engine pylon cracked and experienced substantial structural damage. The flight conducted a precautionary descent and landed at Stapleton International Airport, Denver, Colorado. Preceding the occurrence, the flight was encountering light to occasionally moderate chop, with moderate to severe turbulence forecast.

ACC 121-70 Southwest Aug-03-92 Springfield, MO
Boeing 737-300 Injuries: 1 serious, 1 minor, 65 uninjured.
The flight was in a normal descent deviating around convective activity when the PIC turned on the seat belt sign and instructed the FAs to be seated. One of the FAs on the aft fold down jump seat was in the process of buckling up when severe turbulence was encountered. The FA was thrown into the ceiling and the right rear exit door and sustained serious injuries. Moderate to severe turbulence was forecast and had been reported at higher altitudes. The PIC stated that at the time the airplane was clear of all the activity depicted on his radar.

ACC 121-73 United Jan-09-92 Narita, Japan
Boeing 747-100 Injuries: 1 serious; 234 uninjured.
Pax serious in clear air turbulence climbing thru FL310. Seat belt sign on. Pax in aisle fell & broke his leg. Flight returned to Narita; no injury 16 crew 218 pax; 235 sob.

ACC 121-76 American Jul-01-91 Newark, NJ
Airbus a300-605r Injuries: 2 serious, 10 minor, 204 uninjured.
The a-300 was deviating around a thunderstorm, approximately 25 miles ahead, when severe turbulence was encountered. Several crewmembers and pax were seriously injured. The flight was cruising at 35,000 feet in cirrus clouds. The PIC had put on the seat belt sign prior to the accident.

ACC 121-80 Eastern Oct-03-90 Cape Canaveral, FL DC-9-31
injuries: 1 fatal, 2 serious, 23 minor, 71 uninjured.
The DC-9 encountered turbulence while en route at 31,000 as it flew thru the overhang of a thunderstorm. Flight thru overhangs was contrary to the company ops procedures. Three pax received serious injuries & one of these (84 yrs old) died 20 days after the accident. The medical examiner listed the cause of death as "aspiration pneumonia and pneumothorax due to blunt trauma due to commercial airline turbulence encounter." contributing to the death was "occlusive coronary atherosclerosis." also, 23 pax sustained minor injuries. According to FAs, all injured pax were either standing in the aisle or lavaratories or were in seats without belts on. The seat belt sign had been on since departure; before departure, FAs had briefed the pax to remain seated with belts on at all times while the seat belt light was illuminated. FAs indicated that they had not enforced the seat belt instruction.

ACC 121-81 Southwest Aug-09-90 Corpus Christi, TX
Boeing b737-300 Injuries: 1 serious, 75 uninjured.
The scheduled pax airline flight was in cruise at FL 330 when it encountered clear air turbulence (CAT). A FA was thrown about the cabin and landed on her coccyx bone, which fractured requiring hospitalization for more than 48 hours. The PIC was deviating around cirrus and cumulus clouds when the accident occurred.

ACC 121-90 Delta Aug-26-88 Charleston, SC

Boeing 767 Injuries: 1 serious; 9 minor; 55 uninjured.

The flight encountered severe turbulence in cruise at FL410 as the PIC was deviating around thunderstorm activity. The PIC said the thunderstorm was not visible on radar & cirrus clouds precluded earlier visual detection of the storm. One FA in the rear galley was thrown to the ceiling and sustained serious back injuries. Food & other cabin debris were scattered throughout the cabin. Convective activity was not forecast for the area.

Probable cause: weather condition. Turbulence (thunderstorms)

Seat belt sign..delayed..pilot in command

ACC 121-99 USAir Sep-17-87 Pittsburgh

Boeing 727-200 injuries: 1 serious, 70 uninjured.

While descending out of flt lvl 270 for lndg, USAir flight 10 encountered light to moderate turbulence. Prior to this encounter, the PIC advised all pax and cabin crew to remain seated and to engage their seatbelts. A similar announcement was made by the cabin attendants. An elderly invalid female pax stated she had to use to the restroom prior to lndg since her walking device was being shipped and she would not be able to use the facilities at the arpt. The attendants attempted to dissuade her but she prevailed. Two of them helped her to her feet and were in the process of assisting her down the isle when they were all thrown to the floor by inflight turbulence. The pax sustained two broken bones and other injuries. The flt was given special handling and lndd without further incident.

ACC 121-102 Skyworld Feb-14-87 Durango, Mex

Boeing 707-323b Injuries: 1 fatal; 3 minor; 131 uninjured.

Light chop at 370. Put on sign; 4 pax in aft galley would not sit. The aircraft then encountered a severe jolt. Of the 4 pax standing, an elderly man was killed & 3 received minor injuries. Pax fatal, 3 pax minor; no injury 9 crew & 122 pax.

ACC 129-125 Japan Airlines Mar-31-93 Anchorage

Boeing 747-121 injuries: 5 uninjured

Shortly after the cargo flight took from ANC, it flew into severe turbulence, while climbing through 2000 feet. The number 2 engine & pylon separated. The crew declared an emergency and the flight returned to Anchorage. NTSB found that a strong easterly wind interacted with mountains east of Anchorage, which produced mountain wave activity. The aircraft encountered severe or possibly extreme turbulence. There was evidence that this resulted in dynamic multi-axis lateral loadings that exceeded the ultimate lateral load-carrying capability of the number 2 engine pylon, which had already been reduced by the presence of a fatigue crack near the forward end of the pylon's forward firewall web.

Probable cause: lateral separation of the #2 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. Three flight crewmembers & two deadheading employees (pax) were uninjured.

Inc 121-12 Ccair (USAir express) Apr-22-93 Charlotte, NC

sd 3-60 injuries: 1 minor, 35 uninjured.

At 1420, the commuter flight encountered clear air turbulence in VMC over mountainous terrain. The FA, who was serving beverages, struck the cabin ceiling after a severe jolt; 2 pilots & 33 paxc were uninjured. ATC assigned 10,000 feet, which afforded smooth flight conditions. Later, the flight was assigned 9,000. Shortly after beginning the descent, the airplane encountered a sharp jolt of severe turbulence. The FA was in the galley; she struck the ceiling of the airplane and fell back to the floor. As she tried to rise, she was unsteady and fell again, into the emergency door. She called for help, and a pax came to her assistance. The pax knocked on the cockpit door to notify the flight crew of the FA's injuries. The flight continued to charlotte where the flight attendant received medical assistance.

The FA said that, during the pre-flight briefing prior to departing charlotte, she had requested specific notice from the flight crew when it was safe to begin cabin service. The request was made because of the turbulence she had noted during her commute to work that morning. Once on the ground at Bristol, TN, the request was repeated.

After leaving Bristol, the flight crew chimed the cabin to notify the FA that cabin service could begin. The flight crew said this was the pre-arranged signal. The flight crew stated that when ATC cleared the flight to descend, the FA was notified of the descent via the cabin interphone & advised to be careful due to expected turbulence. The FA reported about half the pax had been served beverages, & that she had returned to the galley for more beverages. While in the galley, the flight experienced "pretty rough stuff real quick," and she fell against the wall. As she tried to set down the beverage tray, the flight crew chimed her. Then, as she replaced the phone, the severe turbulence occurred.

During the flight crew interview, the captain stated that the area forecast is always provided by the flight dispatcher. She did not recall its contents. She indicated that she was not aware of the direction and velocity of forecast winds aloft, nor the winds at altitude during the flight. It was her perception, and the FO's perception, that their flight was the first to encounter the severe turbulence. The PIC stated that she made no additional wx requests at bristol due to what had just been observed on the flight from charlotte. She said that updated wx was received from USAir, & it contained no indication of a change in the turbulence condition.

However, the area forecast issued by the national weather service, Miami, at 0445, referenced AIRMET Sierra. AIRMET Sierra, issued at 0945 on April 22, 1993, indicated that the area through which flight 5052 would traverse was forecast to have light to occasional moderate turbulence below 10,000 feet due to increasing west-northwesterly flow aloft. Low level wind shear was possible. Isolated severe turbulence was forecast across the western Carolinas-eastern Georgia after 1200-1400 with conditions continuing beyond 1600 through 2200. The area covered by the AIRMET extended from 40 nmi east of TRI to Elizabeth City, North Carolina, to 35 nmi north of Vero Beach, FL, to Panama City, FL, to Albany, Georgia, to Chattanooga, Tennessee, to 40 nmi east of TRI. Center weather advisory (CWA) 01, dated April 22, 1993, was issued at 1309. It stated that occasional severe turbulence below 10,000 feet with strong updrafts due to gusty north-northwest winds over rough terrain could be expected from 30 nmi east of TRI to Greensboro to 40 nmi east of Chattanooga, to 30 nmi east of TRI.

Ccair's director of flight ops stated, in a phone conversation on November 16, 1993, that flight crews receive airmets on a clipboard in the dispatcher's office when they are briefed for the flight. Since the CWA referenced above was issued after the flight departed charlotte, it would have been issued at TRI. Subsequently, the director of flight operations reviewed the weather information provided to the flight crew of flight 5052 at TRI and determined that the CWA in fact was not provided to the crew at TRI.

The senior director of flight safety stated that USAir uses the Kavorous System to obtain wx information. According to him, center weather advisories are included on the Kavorous system and are provided to the USAir dispatchers. The dispatcher in turn, provides the advisories to the appropriate flight crews. He also stated that USAir express operators are provided the same wx information from the Kavorous system.

Probable cause: failure of the operator to provide applicable weather information to the flight crew. Factors: CAT, & PIC's failure to use wx information & available assistance

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Inc 121-22 American Jul-10-97 Dickinson, ND

Boeing 757-223 Injuries: 22 minor, 133 uninjured.

At 1541 hours, an American 757-223 encountered severe clear air turbulence in VMC cruise enroute sea-JFK 35 miles SW of Dickinson, ND. There were no injuries to the PIC, FO, 3 FAs, and 128 pax, but 2 FAs & 20 pax sustained minor injuries. The airplane sustained minor damage to the pax service units (psu).

According to the PIC's statement, the aircraft was 80 miles north-northeast of Billings, Montana, in level cruise at FL370. The PIC was flying between widely scattered thunderstorm cells above a 2,000-foot undercast. The collins wxr-700x weather radar was set to the 160 NM scale, and the tilt was 1 to 2 degrees down. The PIC observed one cell 20 NM to his left, towering above his cruise altitude, another cell 40 NM to the right, and a third cell in front and below that "came up independently underneath." he said that up to this point the flight had been smooth, so the seatbelt sign was not illuminated. The airplane encountered severe clear air turbulence for 10 seconds, and the autopilot disengaged, followed by a slight altitude deviation. The PIC was advised of injured pax and FAs, and they were being treated by 3 doctors and a nurse. He diverted to Denver & an uneventful landing. The injured pax & FAs were taken to several local hospitals for treatment. All were released that evening.

The following is based on the incident report and correspondence submitted by American. The flight plan indicated zero for turbulence in the area. The reference is related to the 'turbulence index' that appears on the flight plan on a leg-by-leg basis. The index is an indication of smooth air on average for the entire segment. The segment on which the event occurred extended from billings to Dupree, SD--295 NM.

Turbulence indicators (TIs) are issued by American's meteorologists during preflight planning to inform flight crews & dispatchers about the possibility of non-convective turbulence or clear air turbulence (CAT). They are developed from wx charts depicting jet stream location, satellite imagery & PIREPs. TIs are then input into the flight operating system and used by the flight planning system when calculating flight plans:

0 - smooth
2 - continuous light chop
4 - light to moderate turbulence
6 - moderate to occasional severe turbulence
8 - severe to extreme turbulence

The 0, 2 and 4 TIs do not have any programming impact on the flight planning system. A TI of 6 will force the computer system to seek a more habitable altitude and slow the mach (speed of the aircraft). A TI of 8 will block the altitude or route from consideration of flight planning.

"It is very difficult to strategically forecast rapidly building/decaying convective induced turbulence," the report stated. "The knowledge of thunderstorms implies the possibility of moderate or severe turbulence, wind shear, hail, etc. Once the national weather service (NWS) issued their severe thunderstorm watch (ww), American weather services issued a thunderstorm sigmec (significant meteorological condition) covering it. In fact, the presence of the incident cells was strategically forecast in 2 areas of the flight planning document supplied to the crew during the preflight planning process,"

At 1444, the crew contacted its dispatch office and asked them to transmit SIGMET 57c. It was received at 1448 (see meteorological information). The crew acknowledged the message and indicated they were flying "direct to carleton (Michigan) vortac and north of the affected area." they reported experiencing "occasional light chop at (FL) 370."

The crew statement indicates the flight was operating between widely scattered thunderstorm cells. "This cautious circumnavigation is a tactical maneuver consistent with the crew having knowledge of the thunderstorms and associated turbulence. Considering the normal life cycle of this convective activity, this type of phenomenon can only be detected tactically," the report stated. "A review of the regional composite radar map indicates the national weather service added a severe thunderstorm watch box to the incident area 20 minutes after the event. Initial analysis of ground-based radar data examined by the center for analysis and prediction of storms (caps) at the university of Oklahoma indicates that the particular convective event that is believed to have induced the upset had a life cycle of about 45 minutes."

One pax gave an oral statement to investigators. He described himself as an "amateur meteorologist." he said he was seated at a window seat on the left side of the airplane. They were at 37,000 feet, and the flight attendants had just finished the meal service. The pilot had made an announcement 45 minutes before, advising passengers of the possibility of a bumpy ride ahead and suggested they return to their seats and fasten their seatbelts. He did not think the fasten seatbelts sign was illuminated. He looked out his window and observed a "cloud deck" approximately 90 degrees to the aircraft, or due north. He described this cloud deck as a cumulonimbus, towering higher than the airplane's altitude. The cloud was black inside, and had an anvil. He looked below and saw another cumulonimbus cloud with an anvil, climbing towards the airplane. The pilot then made a "slight right bank, certainly not an evasive maneuver." the passenger thought the pilot was circumnavigating clouds ahead. The airplane "skimmed" over the top of this cloud. The turbulence was encountered on the other side of this building cumulonimbus.

Meteorological information: Dickinson (DIK), North Dakota, METAR (aviation routine weather report) was as follows: 2054z (1454l): wind, 170 degrees at 13 knots; visibility, 20 sm; 25,000 feet scattered; temperature, 32 degrees c.; dew point, 21 degrees c.; altimeter setting, 29.72 inches of mercury; remarks: sea level pressure, 1004.0 millibars.

2150z (1550l): wind, 150 degrees at 13 knots; visibility, 20 sm; ceiling 25,000 feet broken; temperature, 32 degrees c.; dew point, 21 degrees c.; altimeter setting, 29.71 inches of mercury; remarks: towering cumulus distant southwest through west; sea level pressure, 1003.6 millibars.

American said the following NWS convective forecast was supplied to the flight crew:

1755 UTC (1155 MDT) convective SIGMET...none. Area 2...from 50 miles north of Williston, North Dakota, to Rapid City, South Dakota; to Scottsbluff, Nebraska; to Salt Lake City, Utah; to Winnemucca, Nevada; to 40 miles east-northeast of Salmon, Idaho; to Bozeman, Montana; to 40 miles northwest of Havre, Montana; to 50 miles north of Williston, North Dakota. Increasing westerly flow and cooling at mid levels will support thunderstorm activity over central and eastern Montana this afternoon in the vicinity of cold front. Activity will spread into western Dakotas.

The American weather services issued the following forecast that was also made available to the crew for preflight: valid from july 10, 0845 MDT, to july 11, 0300 MDT. Thunderstorm outlook - isolated thunderstorms this morning...will intensify during the afternoon. By 1600 MDT, scattered thunderstorms with some small broken lines are expected over the eastern half of Montana, southern Idaho, and northern Utah. Some thunderstorms spreading eastward into the eastern Dakotas by late afternoon-early evening.

SIGMET 57c was transmitted to the crew at 1448: convective SIGMET 57c valid until 1555 MDT wyoming Colorado from 90 miles east of sheridan, wyoming, to 20 miles northwest of Denver, Colorado; to 30 miles west-northwest of Laramie, Wyoming to 90 miles east of Sheridan, Wyoming. Area thunderstorm moving from 230 degrees at 15 knots. tops to FL 240. hail to 1 inch (diameter)...wind gusts to 50 knots possible.

NTSB's operational factors division conducted a special weather study. According to its report, goes 9 (geostationary operational environmental satellite) photographs showed developing convective activity in the area of the incident. In addition, doppler weather radar data from bismarck, North Dakota, detected weak weather echoes about 9 NM west and 8 NM northwest, and a strong weather echo north-northwest, of the incident area.

The FDR showed the airplane "was cruising at about 37,000 feet. At FDR subframe reference number (srn) 7831, while the aircraft was at 36,992 feet, the vertical acceleration began to oscillate between a maximum and minimum of 2.01 and -0.75 g's. The situation continued for approximately 12 seconds. During this time the lateral and longitudinal accelerations oscillated as well, the angle of attack varied from -4.4 degrees to -23.4 degrees, the aircraft began losing altitude, and the pitch angle dropped from 3.2 degrees to -3.2 degrees. The computed airspeed had increased from 255 to 271 knots just prior to the incident, and a left turn had been executed, changing the heading from 90.5 degrees to 86.0 degrees. Immediately following the incident, a right turn was made, and the heading returned to 90 degrees. The altitude dropped from 36,992 to 36,408 feet over a period of 20 seconds, and the aircraft then began climbing, returning to 36,992 feet at srn 7886."

After reviewing NTSB's report, American made the following observations: "there was a dramatic g-force reversal beginning at time 88325.63 from a +1.773 to a -0.653 at time 88326.13, or 1/2-second. The negative g's persisted for only 3/8-second.

"There was a precipitous drop in computed airspeed from the peak 271 knots to 234 knots over a 4 second time increment. This becomes even more significant if this plunge is given an equivalent mach number at 37,000 feet."

American said the vertical oscillations lasted 15 seconds and varied from +1.975 g's to -0.653 g's, and altitude dropped to a low of 36,408 feet.

Probable cause: an encounter with unforecast convection induced turbulence. Factors: the flight crew's improper evaluation of the weather, and an inaccurate preflight weather briefing by company weather personnel.

Inc 121-23 Continental Jan-20-99 Pacific Ocean, PO

Boeing 747-238b Injuries: 14 minor, 340 uninjured.

At at 1230 hours UTC (just after midnight local), a 747-238b encountered clear air turbulence in dark night VMC at FL330 in cruise near 33 degrees north latitude about 900 nautical miles east of Tokyo, en route Tokyo-HNL. The aircraft sustained only minor interior damage. The 3 pilots were uninjured, as were 11 of 15 FAs & 326 of 336 pax (four FAs & 10 pax sustained minor injuries). The flight had departed Tokyo at 1121 UCT.

The operator reported that "while in cruise at FL330 & [near] 33 degrees north latitude & 155 degrees east longitude, the flight encountered severe [CAT] lasting about 10 minutes. Altitude excursions ranged from plus 500 feet to minus 1000 feet. Though turbulence had been forecasted, no other aircraft had reported encountering any along the route of flight. The night was clear & nothing was displayed on the onboard radar. The PIC had turned on the seat belt sign about 5-8 seconds before the encounter after observing a sudden fluctuation in the oat [outside air temperature] (-37f) as the aircraft entered an area of wave activity. ATC was contacted to secure a block altitude of FL310 to FL330, which was subsequently approved. The decision to continue to destination reflected the time it took to get information from the cabin on the status of the injured & that there would have been a delay in getting a clearance back through the flow of departing flights. The return also would have been back through an area of known turbulence. Several Japanese nurses on board attended the injured & said none were serious. most of the injuries occurred in the back of the aircraft. The injuries consisted of bumps, bruises & minor lacerations. Coordination for medical assistance was done through med link & company dispatch. A total of 14 were taken to 2 medical facilities. All were treated & released."

Meteorological information: the national weather service (NWS) high level significant weather prognostic chart of the northwest pacific area near the time of the event indicated a cold front over the area with a forecast of isolated embedded cumulonimbus clouds. The chart also indicated two jet streams traversing the area, one at 34,000 feet at 160 knots & the other to the south at 39,000 feet at 180 knots. The jet streams generally diverged near the event.

Additionally, a satellite image (gms-5) taken at 1230 UCT indicated a band of high level clouds in the immediate area. The clouds were aligned in a "band" formation oriented northwest to southeast, & perpendicular to the wind flow pattern. This pattern was similar to previous CAT encounters with transverse wave cloud patterns. The CVR remained powered for more than its 30 minute rewrite cycle following the event. The FDR tape was found to be broken in the unit. No useful data could be retrieved.

Inc 129-24 Lufthansa Sep-18-96 San Antonio, TX
Airbus a340-300 Injuries: 8 minor, 166 uninjured.

At 1745, the a-340-300 encountered turbulence near San Antonio while en route Houston-DFW. 8 pax received minor injuries; 12 crew & 154 pax no injury. Of the injured, 1 adult and 3 infants were sent to the hospital, treated and released. The remaining injured pax were treated by paramedics at the airport. The 3 infants were "lap children," ages 3,5 and 16 months, respectively. The aircraft encountered the turbulence 52 minutes after takeoff.

The PIC reported during an interview conducted by FAA that, about 30 minutes after takeoff, while in cruise at FL280, the airborne weather radar indicated a possible area of turbulence ahead. The PIC turned on the seat belt sign. At 20 nautical miles north of three rivers, Texas, the PIC made an announcement over the PA for the FAs to take their seats. The flight encountered "strong" turbulence, 30 miles north of San Antonio, near henly intersection. The PIC did not notify ATC of any injuries until he executed the Acton 4 arrival procedure at DFW, 30 miles south of Acton, at 1810.

A severe turbulence inspection was performed by Lufthansa maintenance personnel at DFW. No structural damage was found, but a cracked overhead plastic light track was found in the main cabin. The aircraft departed DFW at 2100 for the return leg to Frankfurt. Attempts made to obtain a pilot operator report were not successful. Probable cause: turbulence, and failure of pax to properly fasten seat belts and properly hold lap children after the PIC announced expected turbulence.

Inc 129-26 Canada 3000 airline Apr-07-93 Houston
Boeing 757-200 Injuries: 40 uninjured.

At 1255, the 757-200 declared an emergency following a loss of control after encountering extreme turbulence while in cruise in IMC at FL420, about 30 miles south of Houston. The charter flight was enroute from Vancouver, Canada, to San Jose, costa rica. The 9 crew & 31 pax were uninjured.

The captain had turned the seat belt sign on and ordered the cabin crew to secure the cabin as the airplane approached an area of forecasted convective activity. Radar vectors were provided around weather and traffic. The captain stated that their airborne weather radar showed no wx along their route of flight as the airplane encountered light to occasionally moderate turbulence. The airplane was configured for turbulence penetration with engine igniters on "continuous", and manual control of the throttles. A cell appeared ahead of their route of flight, and a 10-degree deviation was requested from ATC and granted. According to the captain, as the turn was initiated to comply with the requested deviation, severe turbulence was encountered. Airspeed was observed to decrease below .68 mach. The FO, who was flying the airplane, "disconnected the autopilot as both pilots pushed the nose down to prevent the airplane from stalling." the PIC estimated a negative 2g force resulted as the attitude of the airplane was changed to an estimated 7 degree below the horizon. As the airplane continued in "moderate to heavy" turbulence, both generators came off line & power was lost to all flight, navigation, and engine instruments. The PIC took the controls & continued to fly with emergency standby instruments, as he declared an emergency. The FO started the APU and completed the emergency procedures to try to regain electrical power. The flight crew reported a strong electrical fire odor, and an "equipment overheat" message appeared on the ecas. About 5 minutes after losing the generators, they both came back on line. The airplane was vectored for an ILS approach to 1-4 at Houston Intercontinental (breaking out of the weather at 600 AGL.) FAA, on behalf of NTSB, found no anomolies or damage related to the airframe or engines.

Inc 129-26 Taca May-24-88 New Orleans

Boeing 737-3t0 injuries: 45 uninjured.

On descent from FL350 for an IFR arroach to New Orleans, the flight crew noted green & yellow returns on wx radar with some isolated red cells left & right of intended flight path. Before entering clouds at FL300, the PIC selected continuous engine ignition & activated engine anti-ice. The crew then selected a route between 2 cells, displayed as red on wx radar. Heavy rain, hail & turbulence were encountered. At FL165, both engines flamed out. The APU was started & ac electric power was restored while descending thru FL106. Attempts to wind-mill restart were unsuccessful. Both engines lit-off by using starters, but neither would accelerate to idle; advancing thrust levers increased egt beyond limits. Engines were shut down to avoid catastrophic failure. An emergency landing was made on a levee (adjacent to the Mississippi River) without further damage to the aircraft. The 38 pax & 7 crew were uninjured; the aircraft sustained minor damage.

NTSB found that the aircraft had encountered a level-4 thunderstorm & engines flamed out, though they had met FAA specs for water ingestion. Aircraft had minor hail damage #2 engine was damaged from overtemp. After the incident, operating manual bulletin 88-5 & ad 6-14-88 were issued to require minimum rpm of 45% & to restore use of autothrust in moderate or heavy precipitation. Engine modification was provided for increased capacity of wtr ingestion. probable cause: double engine flameout due to water ingestion which occurred as a result of an inflight encounter with an area of very heavy rain and hail.

Factor: inadequate design of the engines and the FAA water ingestion certification standards which did not reflect the waterfall rates that can be expected in moderate or higher intensity thunderstorms.

Inc 129-27 Aeromexico Jul-24-84 Key West, FL

DC-8-5 injuries: 1 serious, 8 minor, 145 uninjured.

The captain said the seat belt sign was on for the entire flight from Mexico City to MIA. About 50 miles from Key West, the DC-8 began a descent from FL370. On descent thru 11,500 ft, they encountered severe turbulence while passing thru cumulus clouds; airspeed was 270 kts. Injuries included: one pax serious; 4 pax & 4 FAs minor; no injury to 4 crew & 141 pax. The flight continued to MIA & landed without further incident. A wx study revealed a large area of level 2 to level 5 thunderstorms along the route. There was a convective SIGMET for an area of thunderstorms with tops to 45,000. Numerous pax said no announcements were made to warn them of possible turbulence, except for the seat belt sign. Injuries occurred when occupants were thrown about the cabin or against loose seat belts.

Probable cause: passenger briefing..inadequate..PIC;

Seat belt..improper use of..pax

Factors: weather condition..thunderstorm

Flight into known adverse weather..PIC; weather..turbulence (thunderstorms)

Inc 129-40 British Midland 5-Sep-96 Lambourne, UK

Boeing 737-500 Injuries: no injuries to 6 crew & 64 pax

After an uneventful flight from HTR to brx & a normal turnround, the same crew t/o for HTR. The commander (flying) engaged autopilot 'a' soon after getting established on the departure from brussels; following company sops, he had used auto-throttle from the start of t/o roll. climb & cruise were normal, as were automatic control system operations. On descent, the crew were advised of a delay into HTR and were instructed to 'hold at lambourne. After a 15-minute hold, ATC instructed the crew to leave lambourne at FL80 on a heading of 270°(m) at 220 kt IAS. The PIC selected 'hdg select' and '270°' on the mode control panel (MCP) and, as he crossed lambourne, he rolled out on the required heading.

With the aircraft still level at FL80 and clear of any clouds, the crew were not visually aware of any other aircraft nearby. Neither crew member had their feet on the rudder pedals but the commander had his hands lightly on the control wheel. The crew were then cleared to descend to FL 70 and the commander selected the new altitude, vertical speed ('v/s') & a descent rate of 1,000 FPM.

At 0851, as the aircraft started the programmed descent, the FA entered the cockpit. Both pilots turned to talk to her and the commander took his hands off the control wheel as he turned. Shortly afterwards, both pilots felt the aircraft banking left; the bank appeared rapid but smooth. They both turned back and the commander put his feet on the

rudder pedals and his hands on the control wheel. As he did so, the wheel and rudder felt centered. The aircraft appeared to be banked at least 30° and both pilots believed they were continuing to roll left. The commander immediately disconnected the autopilot and applied right rudder and right control wheel. response to these inputs was rapid and the crew quickly regained control. After confirming that the rudder and aileron trim were neutral and that there were no system abnormalities, the autopilot was re-engaged. It operated correctly for the remainder of the flight, though the commander manually disconnected it very early on the approach.
The FO confirmed the commander's account. He also reached for the controls following the uncommanded roll, which he estimated as 50° bank. He also thought the control wheel & rudder were central before the commander's manual input. Both pilots had experienced wake turbulence before but were not fully convinced that this was a wake encounter. They based this assessment on the fact that it was smoother and more extreme than their previous experience.

A full inspection of the aircraft roll control system, with the assistance of Boeing, showed that the system was correctly rigged, well within the limits required, and functioned normally. The inspection found no evidence of moisture ingress into the connectors of the avionics boxes which affect flight controls, and showed that the protective shields, in the E & E bay behind the nose landing gear, were correctly located and in good condition.

Enquiries to Boeing revealed that the maximum roll control deflection which the autopilot can achieve is, by design, about 4.5° of aileron movement (a control wheel movement of about 20°). Max aileron movement that can be achieved by the pilot is about 20°, which requires a control wheel input of about 82°.

Weather: at 0800 there was a ridge of high pressure over England and Wales with a north easterly airflow over southern England. There were no forecasts for turbulence on the day and no subsequent reports of turbulence. Analysis of the upper soundings suggest a strong inversion around 5,000 feet amsl around lambourne and the wind speed at that level was 060°t/15 kt.

Radar information: the aircraft was 86 seconds or 6.35 NM behind a b767, which was approaching HTR. A b757 which had just departed runway 09 passed at right angles to the track of the two inbound aircraft. As the b757 was 2,300 feet below the 737, it was not the source of the wake. However, the tracks of the 767 and 737 are very close and, given the wind & the 737 descending earlier than the b767, the incident is consistent with a wake encounter from the 767.

FDR: the 737 was level at FL80, heading 270°m and at 220 kt IAS. wind at that level was 057°t/40 kt. At 08:51:10 hrs, the aircraft started a gentle descent. Shortly afterwards, on descent through fl78, small perturbations appeared on the 'normal g' trace. Within 2 seconds, right roll control was applied; initially this kept wings level but, over the next 3 seconds, the aircraft started to roll left, albeit against an increasing aileron deflection to counter this movement. With the aileron then constant at about 5° deflection, the 737 continued to roll left at an increasing rate. The autopilot disengaged and a large right roll demand was applied. Max left roll rate exceeded 18° per second. This occurred after the right roll demand was applied. With the sampling intervals from the DFDR, the aircraft may have achieved a greater bank angle than the recorded 31°. The aircraft recovered to wings level within 4 seconds. There are no subsequent indications of further uncommanded excursions.

Boeing indicated some key attributes of wake encounters. External characteristics include perturbations in airspeed and g's without corresponding changes in pitch; this can also sometimes be seen in random changes in lateral acceleration and angle of attack. Roll characteristics can be much more difficult to discern but include a roll angle that leads to a heading change and a roll rate increasing with time. The g-forces in this incident exhibit these characteristics & are similar to other recorded wake turbulence events.

UK vortex wake categories and spacing criteria are defined in the manual of air traffic services (mats) - part 1 chapter 3 & appendix b. The b767 is included in the heavy category and both the b757 and b737 are in the medium category. The spacing required for a medium behind a heavy is 5 miles. The spacing between two medium category aircraft is 3 miles. However, supplementary instruction no 6 of 1994 to mats acknowledged the unique characteristics of the b757 and raised the spacing requirements of a medium behind a b757 to 4 miles. These figures address aircraft on final but, within the mats, there is an instruction to apply spacing so that "aircraft of a lower weight category do not fly through the wake of an aircraft of a higher category within the area of maximum vortices. Where minimum separation between IFR flights is greater than the vortex wake spacing requirements then the IFR minima shall be applied."

Caa aeronautical information circular (aic) 178/1993 draws attention to the dangers associated with wake vortices. The aic states that separation minima cannot always eliminate a wake turbulence encounter. The objectives of the minima are to reduce the probability of a vortex wake encounter to an acceptable level, and to minimise the magnitude of the upset when an encounter does occur.

Wake vortices are present behind every aircraft but are particularly severe when generated by heavy aircraft. The characteristics of a vortex are determined initially by the aircraft's gross weight, wing span, airspeed, configuration and attitude. Subsequently, these characteristics are altered by interaction between the vortices & the ambient atmosphere. Time to total decay can vary from a few seconds to a few minutes after passage of the aircraft. For practical purposes, the vortex system in the wake of an aircraft may be regarded as being made up of two counter-rotating cylindrical air masses trailing aft from the aircraft, as shown in figure 1. Studies suggest that, at medium level, the two vortices are separated by about 75% of the aircraft's wingspan and, in still air, tend to drift slowly downwards, at about 400 feet per minute, then level off, usually not more than 1,000 feet below the flight path. However, their behaviour is not predictable, particularly their trajectory and decay.

Discussion: the 737bdata shows the classic symptoms of wake turbulence. It was following a b767, but slightly downwind. The separation, at 6.35 miles, was greater than the required minimum of 5 miles. With the 737 starting a descent before the b767, the uncommanded roll started as the 737 was 200 feet below the 767's flight path. Within 3 seconds, ailerons were at max available deflection right under autopilot authority (about 4.5°) and could no longer prevent the aircraft from rolling left. The pilot's response was extremely quick to disengage the autopilot, and exert much greater roll control to counter the uncommanded roll and restore level flight. However, if he had had his hands on the control wheel when the autopilot started to oppose the uncommanded roll, he would have been immediately aware of the wheel moving.

It is not known what would have happened if the autopilot had remained in sole control. In these circumstances, the manufacturers say there is no reason for the autopilot to disconnect automatically. Both pilots considered that the roll would have continued and the FDR indicates that the roll rate was high and increasing and that the aircraft achieved a bank angle of at least 31°. If the 737 had cleared the wake vortex before achieving too high a bank angle, it is probable that the autopilot would have recovered the aircraft to level flight.

This incident illustrates that severe wake turbulence can be encountered even when spacing between aircraft exceeds the recommended minimum. With flow rates at major airports, aircraft are likely to be at the minimum spacing as they maneuver for approach. This incident was controllable with manual inputs but doubt remains as to the outcome if the autopilot had been left to recover the situation. good airmanship dictates 'hands on' monitoring of the autopilot in such situations. After this incident, the carrier began instructing crews that the handling pilot must physically monitor the controls below 10,000 AGL.

APPENDIX D CHARACTERISTICS/INDICATORS

Matthews # **NTSB#** **Aircraft** **Airline**

Location

History of the Flight

1. Date of encounter	Jan/ /1983 ☐unk ☐N/A
2. Time of encounter	(Zulu) (Lcl) ☐ unk
3. Light condition	Day
4. Duration of event	Minutes Second
5. Other flight segments before event	segment(s) unk N/A
6. Location of event	Lat/Long Position
7. Altitude/Height Above Ground	Flight Level MSL AGL
8. Phase of Flight	Cruise
9. Gross Weight	Lbs.
10. Airspeed/Mach	Knots
11. Type of operation	Passenger
12. Orographic characteristics of route at time of event	Unknown
13. Preceding aircraft/nearby	Unknown Distance ☐ Unk
14. Passengers	Total Infants
15. Other	Crew Other Involved

Interaction with Equipment

1. Vertical Mode in use	Mode ☐unk ☐N/A
2. FMS usage	Unknown
3. FMS programmed correctly	Unknown
4. F/D usage	Unknown
5. Autopilot usage	Unknown
6. Autothrottle usage	Unknown
7. Weather Radar	Unknown Scale (Range( ) Stab/tilt Cells seen Turbulence indication:
8. EFIS Usage	Unknown
9. Other	

Personnel Information

1. Pilot flying during event	Unknown
2. Number of cockpit crew present at time of encounter	Number
3. Captain (or PIC) total flying hours	hours ☐unk ☐ N/A
4. Captain (or PIC) hours in aircraft type	hours ☐unk ☐ N/A
5. Captain (or PIC) experience on route	Unknown
6. Captain (or PIC) hours in aircraft type in last 30 days	hours ☐unk ☐ N/A
7. First officer (or PNF) total flying hours	hours ☐unk ☐ N/A
8. First officer (or PNF) hours in aircraft type	hours ☐unk ☐ N/A
9. First officer (or PNF) experience on route	
10. First officer (or PNF) hours in aircraft type in last 30 days	hours ☐unk ☐ N/A
11. Number of cabin crew on board/number required	On Board Number Required
12. Cabin crew duty day length	Legs Hours

13. Cabin crew total experience	
14. Cabin crew experience on type	
15. Diversion	No
16. Determining Factors	Pilot Decision
17. Other	

Airplane Information

1. Aircraft type and model	Type Model
2. FMS equipped	Unknown
3. EFIS equipped	Unknown
4. ACARS equipped	Unknown
5. GPS/INS equipped	Unknown
6. Autopilot equipped	Unknown
7. Autothrottle equipped	Equipage unknown Mode unknown Operation unknown
8. EICAS/ECAM equipped	Unknown
9. Aircraft equipment malfunctions in flight, I.e. Did not function as designed	List pertinent nonfunctioning equipment
10. Airplane dispatched with pertinent MEL items	Unknown
11. Relevant maintenance history problems	Unknown
12. Flight Recorder	Unknown Number of channels Data available? No Maximum accelerations: + g / - g
13. Cockpit voice recorder data available in report	No
14. Annunciations present	Unknown
15. TCAS: Aircraft in the vicinity	Unknown
16. Spoiler position at event	Position
17. Weather radar capability	Unknown
18. Load Alleviation System	Unknown
Cabin Design:	
18. Galley location	Forward/Mid/Aft Lower Lobe/Upper Deck
19. Jump seat location	Forward/Mid/Aft
20. Crew Rest seat location	Unknown
21. Type of carts	Unknown
22. Cart Location at time of event	Unknown
23. Seats	Number Layout
24. Handholds Available	Unknown Type and Location
25. Other	

Meteorological Information

1. Weather status at time of event	VMC Winds: deg / knots
2. Visibility in miles at event site at time of event	miles Restrictions None
3. Was turbulence forecast	Unknown Forecast Product (none)
4. Turbulence encountered	Type Severity Unknown Time Z Duration min. sec.
5. Reported turbulence	Unknown Source
6. Turbulence felt prior to event	Unknown
7. Visual indicators of turbulence	Unknown If yes, specify
8. Temperature variation noted prior to event?	Unknown

9. Wind variation noted prior to event?	Unknown
10. Synoptic overview of conditions at time of event	Jet stream location Fronts/lows/highs
11. Mesoscale overview at location of event	Convection present Relative to route of flight
12. General Meteorological Environment (Forecast)	Source Winds/wind gradient Temperature gradient Tropopause height Presence/type of clouds/location Presence/type pressure patterns VMC/IMC Precipitation Visibility Clear
13. General Meteorological Environment (Actual)	Source Winds/wind gradient Temperature gradient Tropopause height Presence/type of clouds/location Presence/type pressure patterns VMC/IMC Precipitation Visibility Clear
14. Products	Wind Profiles (200 NM) Profiler data/Doppler Satellite images (IR/Vis/other) Jet Stream Standard Pressure level charts Temperature Tropopause Turbulence products (AWC) Company specific products
15. Aircraft derived weather data (in situ)	No
16. Meteorological case studies available for event	No Source:

17. Product	Receive? Yes/No	Source (ATC/ Preflight Briefing/ Inflight Broadcast/ HIWAS/ Company/ Pilot-to-Pilot Party Line)	Turbulence Severity	Received by Pilot?
CWA	No	N/A	N/A	N/A
PIREP	No	N/A	N/A	N/A
AIRMET	No	N/A	N/A	N/A
SIGMET	No	N/A	N/A	N/A
AREA FORECAST	Yes	Preflight Briefing	None	Yes
DISPATCH	Yes	Preflight Briefing	None	Yes
Other:	No	N/A	N/A	N/A

18. Other	

Flight Crew Performance

1. Flight navigation mode	Unknown		
2. Captain number of hours for	Rest	Duty	Flight
3. First Officer number of hours for	Rest	Duty	Flight

4. Distractions	Unknown
Flight Planning	
5. Pilot brief Cabin Crew - preflight brief?	Unknown
6. Pilot response during encounter	Unknown
Flight Attendant/Cabin Crew Performance	
7. Locations of persons injured in cabin during encounter	Standing/aisle
8. Seat belt enforcement/announcements before event	Unknown
9. Seat belt sign	On
10. Did the flight crew coordinate beverage service with expected/forecast turbulence?	Unknown
11. What are the criteria for delay/suspension of meal/drink service for turbulence?	☐None Brief description:
12. Service level/Phase of flight	Unknown
13. Service items/Carts at event	Unknown
14. Cabin preparation for turbulence	Unknown
15. Nature of warning	Unknown 0 Minutes of warning
16. Cockpit warning to be seated given to flight attendants	Unknown
17. Passenger Performance	Number out of seats Heed warning?
18. Seat belt light status	At start of event On During/after event On Flight Attendant announcement made? Yes
19. Other	

Air Traffic System

1. Turbulence PIREP available to ATC	Unknown
2. Turbulence PIREP relayed by ATC	Unknown
3. SIGMET relayed by ATC	Unknown
4. CWA relayed by ATC	Unknown
5. Other aircraft reporting turbulence on radio frequency	Unknown
6. Radio frequency congested	Unknown
7. Route change before encounter:	Requested: No Approved: N/A Executed N/A
8. Altitude Change before encounter:	Requested: No Approved: N/A Executed N/A
9. Altitude change approved	Unknown
10. Controller experience	Total Facility/Sector
11. Controller workload	Unknown
12. Did ATC record turbulence information on HIWAS	Unknown
13. Other	

Company/Flight Operations Information

1. Is there a seat belt light procedure for turbulence	Yes Brief description
2. Is there a Seat belt light procedure for enforcement	Yes Brief description

3. Below what altitude are Flight Attendants routinely required to be seated/restrained?	Climb (Altitude) Descent (Altitude) OR Distance from Airport (Miles) No Procedure
4. What is procedure for flight planning in known turbulence?	Procedure: Criteria used:
5. Diversion for turbulence policy	Yes
6. Thunderstorm avoidance procedures	Yes Describe
7. Turbulence avoidance procedures	Yes Describe
Dispatch Issues	
8. Company have meteorology department	Yes
9. Is Company EWINS certified	Yes
10. Does Company explicitly consider turbulence-induced deviations in fuel planning?	Yes
11. Fuel available for deviations in altitude/route	Yes
12. Other	

Injury Characteristics

Passenger Injuries	
Infants	
1. Infant seats in use	Unknown
2. Location of injured infants within aircraft	No: Fore Mid-Section Aft Number with seat belt fastened Number standing Number seated
3. Type of injuries sustained	
4. Injuries sustained from:	Unknown
5. Injury Category	None
Adults	
6. Location of injured adults within aircraft	No: Fore Mid-Section Aft Number with seat belt fastened Number standing Number seated
7. Type of injuries sustained	
8. How injuries were sustained	Unknown
9. Injury Category	None
Flight Attendants	
10. Location of injured Flight Attendants within aircraft	No: Fore Mid-Section Aft Number with seat belt fastened Number standing Number seated
11. Type of injuries sustained	
12. How injuries were sustained	Unknown
13. Injury Category	Serious
14. Category/number of injuries	Serious Minor
15. Flight Attendant Staffing	
16. Aircraft damage	None
17. Passenger response to alert	
18. Other	

APPENDIX E STANDARD PROBLEM STATEMENTS

NOTE 1: The Turbulence JSAT Team developed and numbered a complete new set of standard problem statements. However, some are duplicates of standard problem statements developed in previous JSATs. Duplicates show both the 600-series turbulence number and the original number, i.e "601/303"..

NOTE 2: The"67x" series was developed to be used as a placeholder for different types of turbulence in the event sequences. No interventions map to these 67x standard problem statements.

Flight-Crew

No.	Standard Problem Statement	Definition
601/ 303	Flight Crew – Failure to process and interpret available, relevant data	Flight crew failure to process and interpret available, relevant data, including decisions arising from Collaborative Decision-Making.
602/ 16	Failure to communicate with cabin crew/Passengers	Failure of flight crew to communicate to cabin crew and/or passengers information about impending turbulence or directions to be seated/restrained.
603- 10	Failure to follow procedures	Failure of flight crew to follow established procedures.
604/ 204	Not adequately prepared for the task	Flight crew not adequately prepared with briefings, in assessment of weather factors or other information received, or not mentally prepared.

Cabin-Crew

New	Standard Problem Statement	Definition
611	Flight Attendant not seated or not restrained when seated	Flight Attendant was not seated and/or restrained because of priority of duties, inadequate time to comply, inadequate warning time, equipment failure, did not understand or take the warning seriously or did not hear the warning.
612	Inadequate communications to passengers	Failure of cabin crew to communicate to passengers impending information about turbulence or directions to be seated/restrained.

Air Traffic Control

New	Standard Problem Statement	Definition
621	Insufficient separation behind aircraft that generate wake turbulence	Failure of the air traffic control system to ensure appropriate separation behind aircraft that generate significant wake turbulence
622	ATC delay in processing clearance requests	Failure of the air traffic control system to process clearance requests in a timely enough manner to allow an aircraft to avoid turbulence in both domestic and oceanic airspace.
623/ 103	Failure to collect and disseminate relevant weather information to flight crews	Failure of the air traffic control system to collect and disseminate relevant weather information to flight crews, including PIREPs.
624	ATS/Airlines – Procedures limited or no collaborative decision making by ATC and the airlines	Lack of, or limited airline or air traffic system procedures in place to participate in collaborative decision-making or lack of confidence in the agreed upon DCM plan.

Aircraft Equipment

New	Standard Problem Statement	Definition
631/ 57	Design shortcomings -	Aircraft design, including cabin design was not sufficient to allow flight attendants and/or passengers to escape injury.
632	Inadequate means to secure equipment/service items	Aircraft/cabin design had inadequate means to secure equipment/service items in order that they not cause injuries to flight attendants or passengers.

Passenger

New	Standard Problem Statement	Definition
641	Passenger out of seat or unrestrained in seat	Passenger was not seated and/or restrained because of inadequate time to comply, inadequate warning time, equipment failure, did not understand or take the warning seriously or did not hear the warning.

Airline Operations

New	Standard Problem Statement	Definition
651/ 32	Failure of the airline to adequately collect, analyze, forecast and disseminate available turbulence information.	Airline failure to adequately collect, analyze, forecast and disseminate available turbulence information.
652	Failure to effectively use the wx information to make routing decisions	Airline failure to effectively use weather information received, including information received in the CDM process, to make routing decisions that successfully avoid turbulence.
653/ 35	Airline Operations- inadequate safety data sharing	Failure to share safety significant data within airlines and the air traffic management community
654	Turbulence avoidance and mitigation policies and procedures non-existent or inadequate.	Lack of, or inadequate airline policies and procedures that encourage turbulence avoidance and mitigation during pre-flight and in-flight. This includes airline culture that does not encourage avoidance and mitigation.
655/ 20	Airline Operations – Lack of Training	Airline training for all crewmembers and dispatchers failed to adequately address requirements necessary for the crew to successfully avoid or mitigate turbulence.

Weather Information/Weather Providers

New	Name	Definition
661	Weather information from the source is inadequate or non-existent	Weather information (forecast and observations) from Government and private sources (airlines, flight crews, on-board equipment, private weather contractors) was inadequate or non-existent.
662	No real-time turbulence detection and avoidance capability	Lack of real-time turbulence detection and avoidance capability for decision-makers (flight crew, air traffic control and dispatchers).

Types of Turbulence

New	Name	Definition
671	Aircraft encounters turbulence in or near convection	Turbulence type was convective.
672	Aircraft encounters turbulence in or near wake	Turbulence type was wake..
673	Aircraft encounters turbulence in or near clear air	Turbulence type was clear air.
674	Aircraft encounters turbulence in cruise in or near mountain waves	Turbulence type was mountain wave.
675	Aircraft encounters turbulence on climb or descent in vicinity of terrain	Turbulence type was near terrain.

APPENDIX F PROBLEM FREQUENCY

Problem Statement	601	602	603	604	611	612	621	622	623	624	631	632	641	651	652	653	654	655	661	662
Accident /Incident Number																				
121-1		3			1				1		2	1					1			1
121-2	1	3		2	3						7	1	1	2	1		1	1	2	
121-4			2														1	1		
121-5	3	2	1	1	1						2	1			1		1	1		
121-9									1		1		1				1			
121-16	1				1						1				1		2	3		
121-18		1			1	1					1		1						1	1
121-19					2					1	2		2					1	1	4
121-20		1						1			1	1								
121-21	4	1		1	3	2		2	2	2	3	1	3	1	2	2	4	1	1	1
121-24	3	2	2	1					2								1			1
121-25	1	1							1		2		1						1	1
121-27	2										1				2		5	8	1	1
121-33			1	1	1						2		1	1			1			2
121-34		1		1							2	1	1				1		1	1
121-37					2						2						1		2	2
121-39																			2	2
121-40					2						1		1							
121-41											2	1							2	2
121-43	2										1		1	4			1		1	2
121-44					2						2						1			2
121-47											1		1				1			

Problem Statements	601	602	603	604	611	612	621	622	623	624	631	632	641	651	652	653	654	655	661	662
121-48			1						1		3		1	1			1	2		1
121-49											1		2	1				1	2	2
121-53													1						2	2
121-54	1				1				1		3			1				1		2
121-55											1			1					2	2
121-57					1						1							1	2	2
121-59		1			1	1					2		1				2	1		2
121-61	1																1			
121-64					1															
121-66	1				1													1		1
121-69	1									1				1	1		1			
121-70					2															1
121-73	1												1						1	
121-76					1								1							1
121-80			1																	
121-81	1				1															
121-90				1	1				1		1						1		1	
121-99					1								2				1			
121-102	1			1		1							1	1					1	1
129-125																			1	
INC121-9											1					1			1	
INC121-12				1	1									2			1	1	1	1
INC121-22	1		1						1					1	1		1	2	2	1
INC121-23	1										1				1			1	1	1
INC121-35					1						1								1	
NAVY9											2							1	1	2

Problem Statements	601	602	603	604	611	612	621	622	623	624	631	632	641	651	652	653	654	655	661	662
GALLAG DEN-SNA		**1**			**1**				**1**		**1**			**1**	**1**				**1**	**1**
GALLAG LAX-SFO					**1**															**1**
GALLAG MCI-DEN	**1**			**1**						**3**					**3**			**1**		**1**
TOTALS	**27**	**17**	**9**	**11**	**34**	**5**	**0**	**3**	**12**	**7**	**54**	**7**	**24**	**18**	**20**	**3**	**32**	**29**	**35**	**48**

APPENDIX G INJURY FREQUENCY

	Flight Attendant Serious	Flight Attendant Minor	Passenger Serious	Passenger Minor	Deaths
Accident/Incident Number					
121-1	1				
121-2		4	1	67	
121-4		4	1	4	
121-5	1				
121-9			1		
121-16	1				
121-18		3	2	15	
121-19	1	2		3	
121-20			1		
121-21	1	7	12		1
121-24	1	2		1	
121-25			1		
121-27	1	3			
121-33	1	1			
121-34	1	3		2	
121-37	2				
121-39			3	1	
121-40		1	1	1	
121-41	1				
121-43			3	17	
121-44	1				
121-47			1		
121-48			1	5	
121-49			1		
121-53			1	5	
121-54	1				
121-55	1				
121-57	1				
121-59			1	2	
121-61	1				
121-64	1				
121-66	1				
121-69	None				
121-70	1	1			
121-73			1		
121-76	1		1	10	
121-80			2	23	1

	Flight Attendant Serious	Flight Attendant Minor	Passenger Serious	Passenger Minor	Deaths
121-81	**1**				
121-90	**1**	**6**		**3**	
121-99			**1**		
121-102				**3**	**1**
129-125	**NONE**				
INC121-9		**3**		**3**	
INC121-12		**1**			
INC121-22		**2**		**20**	
INC121-23		**4**		**10**	
INC121-35		**2**		**4**	
NAVY9	**1 Crew**				
GALLAG DEN-SNA		**2**			
GALLAG LAX-SFO	**1**		**16**		
GALLAG MCI-DEN	**1**				

APPENDIX H INTERVENTION STRATEGIES
(Sorted by Number)

601 To ensure effective cockpit-cabin communication, FAA should require that air carriers' operating specifications and training programs include standardized procedures and phraseology for pre-flight and in-flight communication of turbulence hazards, degree of hazard and all clear declarations

602 To improve the timeliness and effectiveness of turbulence warning dissemination and damage reports, airlines should develop and implement instant two-way communications capability between cabin crew and flight crew anywhere in the aircraft at all times.

603 To ensure that passengers are aware of potential hazards, air carriers should develop and implement standardized pre-flight briefings to passengers (including multi-lingual briefings, as appropriate) that provide practical information about anticipated turbulence hazards and emphasize passenger responsibility for seat belt compliance.

604 To gain compliance by passengers who otherwise ignore seating or seat belt instructions, air carriers and Government should develop and implement enforcement policies and procedures on how to deal with passengers' who do not heed warnings.

605 To provide immediate warning to the cabin crew and passengers, air carriers should develop and implement automated aural or visual cabin alerting systems.

606 To alleviate the effect of encountering turbulence, researchers, manufacturers and air carriers should develop and implement a capability to quickly and automatically reconfigure the flight control system and adjust airspeed to mitigate forces acting upon occupants

607 To assure availability of the most current and highest quality turbulence information, air carriers should audit their current systems for receiving, analyzing and disseminating weather products and ensure that dispatchers and flight crews effectively obtain and use all available turbulence information contained currently in SIGMETS, PIREPS and AIRMETS, and in Flight Watch and HIWAS services.

608 To reduce inadvertent flight into turbulence associated with convection, industry and government should develop and implement separation standards that use visual cues and indications from on-board systems (such as radar, outside air temperature, etc).

609 To better manage turbulence risks, air carriers should improve fundamental knowledge about meteorology and types of turbulence by providing adequate initial and recurrent training to flight crews, meteorologists and dispatchers in turbulence assessment, recognition and avoidance.

610 To improve the effectiveness of flight planning and decision-making processes, government and industry should continue to develop collaborative decision making (CDM) and joint training programs in order to enhance effective CDM among dispatchers, meteorologists, ATC and flight crews, with emphasis on joint participation in flight planning, timely communication (including CPDLC, voice, etc.), in-flight decision making and ensuring that all functions share the same sources of weather information.

611 To provide more flexibility in route selection to avoid turbulence in International Airspace, the FAA and other governmental agencies should establish additional transoceanic tracks.

612 To more accurately depict low reflectivity thunderstorms, manufacturers and air carriers should develop and implement improved detection equipment and associated operating procedures.

613 To depict the best route of flight around turbulence, air carriers and manufacturers should develop and implement real-time graphical weather displays and turbulence alerts to the flight deck.

614 To provide clear detection and depiction of turbulence location and intensity, Government and industry should develop and implement methods to synthesize available airborne, ground-based and satellite data, forecasts, "nowcasts" and meteorological models.

615 To improve communication among providers and users of turbulence information, Government and industry should standardize ground and in-flight indications of turbulence hazard intensity and the phraseology used in dissemination, and should ensure that operators, flight crews, and ATC receive the same information.

616 To support a primary strategy of turbulence avoidance, air carriers should implement "best practices," as outlined in FAA Advisory Circular AC00-30b. These practices should include, but not be limited to, establishing full meteorological capabilities in-house or through a vendor, the establishment of a turbulence charting and alerting program that identifies current risks and areas where turbulence and mountain waves are most common, etc.

617 To ensure that all users and service providers have real-time access to PIREPs and other time-critical weather information, government and industry should develop a capability to share such information.

618 To obtain more PIREPs in conformance with the AIM, pilots should report turbulence in the form of PIREPs to ATC (may be broken out to specific ATC elements.

619 To make forecasts and warnings of turbulence and other hazardous weather more spatially and temporally precise, accurate and more applicable to specific routes and specific aircraft types and categories, Government, weather providers and the air carriers should improve the accuracy of those products.

620 To improve the accuracy of turbulence forecasts, air carriers and FAA should expand the forecasting techniques and CDM practices currently employed in the Strategic Planning Implementation Team and CCFP to turbulence forecasting

621 To improve the collection and dissemination of objective real-time turbulence reports, air carriers and manufacturers should continue to develop and implement automatic methods for detecting turbulence encounters and reporting them electronically (along with other relevant weather information) to all users

622 To reduce flight attendants' exposure to turbulence, during climb and descent, air carriers should establish and implement a policy and related SOPs that require all flight attendants and passengers to be seated and restrained from takeoff to cruise altitude and from FL200 through landing.

623 To reduce flight attendants' exposure to turbulence while performing seat belt monitoring, FAA should require and air carriers should develop and implement clearly stated policies and standard operating procedures, to be included in flight attendant manuals, that allow cabin crew to prioritize, without repercussion, immediate duties and cabin service schedules, including the option to be seated while making seatbelt announcements in response to anticipated turbulence hazards or warnings.

624 To equip flight attendants with the insights and knowledge required to prioritize cabin duties versus the risk of turbulence injuries, FAA should require air carriers to develop and implement training for flight attendants in turbulence hazards, aircraft behavior in turbulence, and the need to ensure their own safety.

625 To reduce injuries to passengers and flight attendants during unexpected turbulence, FAA, air carriers and manufacturers should equip cabin interiors with handholds and other restraint systems or padding in appropriate locations (e.g., aisles, galleys, arm rests, lavatories, and jumpseat areas) and should consider locating jumpseats near work areas or installing auxiliary jumpseats adequate for turbulence encounters (but not for use during takeoff or landings).

626 To reduce injuries from ineffective or failed restraint systems, air carriers and manufacturers should consider the redesign of such systems to ensure that flight attendants and passengers, including small children, are secure during turbulence.

627 To reduce injuries that result from overhead storage bins that open during turbulence encounters, manufacturers should evaluate and redesign, as applicable, storage bins and all other items suspended overhead from the ceiling.

628 To detect and warn of imminent turbulence encounters, manufacturers, air carriers and Government should develop and implement an airborne, ground-based or satellite system that warns of impending turbulence immediately ahead of the aircraft.

629 To reduce injuries from inadvertent contact with service equipment (such as serving carts and hot beverage equipment), manufacturers, air carriers and FAA should test, redesign, and implement additional systems to secure service and equipment items, such as cart-restraint floor tracks or “mushrooms”, retractable arms, and sealed hot beverage containers.

630 To ensure passenger adherence, DOT and FAA and air carriers should continually promote seat belt usage and compliance with advisories and warnings by extending the “Vince and Larry” Seat Belt Campaign to aviation and by other public service initiatives (e.g. videos, airport signage and posters, ticket covers, napkins, brochures, web sites, etc.).

APPENDIX I TURBULENCE INTERVENTION SUMMARY

Intervention Number	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625
Accident / Incident Number																									
121-1	**1**	**1**			**1**	**1**	**1**			**1**		**1**	**1**	**1**		**1**	**1**						**1**	**1**	**1**
121-2	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**		**1**	**1**	**1**
121-4	**1**		**1**					**1**	**1**	**1**		**1**				**1**	**1**							**1**	
121-5	**1**	**1**					**1**	**1**	**1**	**1**			**1**	**1**		**1**				**1**		**1**	**1**		**1**
121-9			**1**	**1**					**1**	**1**		**1**	**1**	**1**		**1**	**1**								**1**
121-16	**1**	**1**			**1**		**1**	**1**	**1**	**1**		**1**				**1**								**1**	
121-18	**1**		**1**	**1**									**1**	**1**					**1**					**1**	**1**
121-19	**1**				**1**	**1**	**1**		**1**	**1**			**1**	**1**		**1**			**1**						**1**
121-20	**1**									**1**			**1**	**1**			**1**								
121-21	**1**		**1**	**1**			**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**		**1**		**1**				**1**	**1**	**1**
121-24	**1**	**1**			**1**			**1**	**1**	**1**				**1**					**1**	**1**	**1**				
121-25			**1**	**1**			**1**		**1**				**1**	**1**			**1**		**1**						**1**
121-27	**1**	**1**					**1**	**1**	**1**	**1**			**1**	**1**		**1**	**1**		**1**	**1**			**1**		**1**
121-33	**1**						**1**	**1**	**1**			**1**		**1**	**1**	**1**				**1**					**1**
121-34	**1**	**1**		**1**	**1**			**1**	**1**				**1**	**1**	**1**				**1**				**1**		**1**
121-37						**1**		**1**	**1**			**1**	**1**	**1**		**1**			**1**			**1**		**1**	**1**
121-39					**1**							**1**	**1**	**1**		**1**			**1**						
121-40			**1**	**1**																			**1**	**1**	**1**
121-41						**1**						**1**	**1**	**1**		**1**			**1**						
121-43			**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**	**1**	**1**		**1**			**1**						**1**
121-44				**1**		**1**		**1**	**1**			**1**	**1**	**1**		**1**			**1**			**1**	**1**	**1**	**1**
121-47			**1**	**1**				**1**	**1**	**1**	**1**			**1**		**1**			**1**						**1**
121-48	**1**	**1**			**1**	**1**	**1**		**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**		**1**		**1**				**1**
121-49			**1**	**1**	**1**	**1**	**1**	**1**	**1**			**1**	**1**	**1**		**1**			**1**						**1**
121-53			**1**	**1**		**1**						**1**	**1**	**1**		**1**			**1**						
121-54						**1**						**1**	**1**	**1**		**1**			**1**			**1**	**1**	**1**	**1**
121-55						**1**						**1**	**1**	**1**		**1**			**1**						**1**

Intervention Number	601	602	603	604	605	606	607	608	609	610	611	612	613	614	615	616	617	618	619	620	621	622	623	624	625
Accident / Incident Number																									
121-57						1			1			1	1	1		1			1			1	1	1	1
121-59	1	1			1	1		1	1		1	1	1	1		1			1				1	1	1
121-61							1	1	1							1									
121-64	1																					1		1	
121-66								1	1							1						1			1
121-69	1					1	1		1	1		1	1	1		1		1	1	1	1				
121-70	1	1			1																		1		
121-73			1	1			1						1	1		1	1		1						
121-76	1			1	1	1						1			1	1						1		1	
121-80			1	1				1	1							1							1		1
121-81	1							1	1																
121-90			1						1			1	1	1					1						1
121-99			1	1				1	1							1								1	1
121-102	1	1	1	1	1	1	1						1			1	1	1	1		1		1		1
129-125							1	1	1	1				1		1	1		1						
INC121-9													1	1											
INC121-12	1	1			1	1	1	1					1			1	1	1	1		1	1	1	1	1
INC121-22	1		1				1	1	1	1		1	1	1		1	1	1	1	1	1				
INC121-23		1					1	1	1	1	1	1	1	1					1	1	1				
INC121-35												1										1			
NAVY9								1	1			1	1	1		1			1						1
GALLAG DEN-SNA	1	1	1		1	1	1	1	1	1		1	1		1	1	1	1	1		1	1	1	1	1
GALLAG LAX-SFO	1	1						1																	
GALLAG MCI-DEN							1	1	1	1			1		1	1				1					
TOTALS	25	15	18	17	16	18	22	25	34	20	6	25	35	33	8	35	15	6	30	7	8	10	16	17	28

APPENDIX J TURBULENCE INTERVENTION STRATEGIES

(Sorted by Overall Effectiveness)

Int #	INTERVENTIONS	P	C	A	Overall Effectiveness
616	To support a primary strategy of turbulence avoidance, air carriers should implement "best practices," as outlined in FAA Advisory Circular AC00-30b. These practices should include, but not be limited to, establishing full meteorological capabilities in-house or through a vendor, the establishment of a turbulence charting and alerting program that identifies current risks and areas where turbulence and mountain waves are most common, etc.	5.4	4.9	5.3	3.9
622	To reduce flight attendants' exposure to turbulence, during climb and descent, air carriers should establish and implement a policy and related SOPs that require all flight attendants and passengers to be seated and restrained from takeoff to cruise altitude and from FL200 through landing.	5.5	4.8	4.9	3.6
621	To improve the collection and dissemination of objective real-time turbulence reports, air carriers and manufacturers should continue to develop and implement automatic methods for detecting turbulence encounters and reporting them electronically (along with other relevant weather information) to all users.	5.7	4.7	4.4	3.3
628	To detect and warn of imminent turbulence encounters, manufacturers, air carriers and Government should develop and implement an airborne, ground-based or satellite system that warns of impending turbulence immediately ahead of the aircraft.	5.2	4.2	5.2	3.2
613	To depict the best route of flight around turbulence, air carriers and manufacturers should develop and implement real-time graphical weather displays and turbulence alerts to the flight deck.	5.3	4.6	4.3	2.9
601	To ensure effective cockpit-cabin communication, FAA should require that air carriers' operating specifications and training programs include standardized procedures and phraseology for pre-flight and in-flight communication of turbulence hazards, degree of hazard and all clear declarations	4.4	4.9	4.8	2.9
619	To make forecasts and warnings of turbulence and other hazardous weather more spatially and temporally precise, accurate and more applicable to specific routes and specific aircraft types and categories, Government, weather providers and the air carriers should improve the accuracy of those products.	5.5	4.0	4.7	2.9
623	To reduce flight attendants' exposure to turbulence while performing seat belt monitoring, FAA should require and air carriers should develop and implement clearly stated policies and standard operating procedures, to be included in flight attendant manuals, that allow cabin crew to prioritize, without repercussion, immediate duties and cabin service schedules, including the option to be seated while making seatbelt announcements in response to anticipated turbulence hazards or warnings.	5.0	4.4	4.4	2.7
614	To provide clear detection and depiction of turbulence location and intensity, Government and industry should develop and implement methods to synthesize available airborne, ground-based and satellite data, forecasts, "nowcasts" and meteorological models.	5.0	4.1	4.5	2.6
617	To ensure that all users and service providers have real-time access to PIREPs and other time-critical weather information, government and industry should develop a capability to share such information.	5.0	4.1	4.1	2.3
608	To reduce inadvertent flight into turbulence associated with convection, industry and government should develop and implement separation	4.7	3.8	4.5	2.2

Int #	INTERVENTIONS	P	C	A	Overall Effectiveness
	standards that use visual cues and indications from on-board systems (such as radar, outside air temperature, etc).				
609	To better manage turbulence risks, air carriers should improve fundamental knowledge about meteorology and types of turbulence by providing adequate initial and recurrent training to flight crews, meteorologists and dispatchers in turbulence assessment, recognition and avoidance.	4.5	3.6	4.7	2.1
624	To equip flight attendants with the insights and knowledge required to prioritize cabin duties versus the risk of turbulence injuries, FAA should require air carriers to develop and implement training for flight attendants in turbulence hazards, aircraft behavior in turbulence, and the need to ensure their own safety.	4.5	3.7	4.4	2.0
618	To obtain more PIREPs in conformance with the AIM, pilots should report turbulence in the form of PIREPs to ATC (may be broken out to specific ATC elements.	5.0	3.7	3.9	2.0
610	To improve the effectiveness of flight planning and decision-making processes, government and industry should continue to develop collaborative decision making (CDM) and joint training programs in order to enhance effective CDM among dispatchers, meteorologists, ATC and flight crews, with emphasis on joint participation in flight planning, timely communication (including CPDLC, voice, etc.), in-flight decision making and ensuring that all functions share the same sources of weather information.	4.5	3.4	4.7	2.0
612	To more accurately depict low reflectivity thunderstorms, manufacturers and air carriers should develop and implement improved detection equipment and associated operating procedures.	4.6	4.1	3.5	1.8
625	To reduce injuries to passengers and flight attendants during unexpected turbulence, FAA, air carriers and manufacturers should equip cabin interiors with handholds and other restraint systems or padding in appropriate locations (e.g., aisles, galleys, arm rests, lavatories, and jumpseat areas) and should consider locating jumpseats near work areas or installing auxiliary jumpseats adequate for turbulence encounters (but not for use during takeoff or landings).	4.3	3.7	4.1	1.8
602	To improve the timeliness and effectiveness of turbulence warning dissemination and damage reports, air carriers should develop and implement instant two-way communications capability between cabin crew and flight crew anywhere in the aircraft at all times.	4.0	4.0	4.0	1.8
604	To gain compliance by passengers who otherwise ignore seating or seat belt instructions, air carriers and Government should develop and implement enforcement policies and procedures on how to deal with passengers' who do not heed warnings,	4.0	4.0	4.0	1.8
607	To assure availability of the most current and highest quality turbulence information, air carriers should audit their current systems for receiving, analyzing and disseminating weather products and ensure that dispatchers and flight crews effectively obtain and use all available turbulence information contained currently in SIGMETS, PIREPS and AIRMETS, and in Flight Watch and HIWAS services.	3.9	3.7	4.3	1.7
606	To alleviate the effect of encountering turbulence, researchers, manufacturers and air carriers should develop and implement a capability to quickly and automatically reconfigure the flight control system and adjust airspeed to mitigate forces acting upon occupants.	3.9	3.7	4.3	1.7
605	To provide immediate warning to the cabin crew and passengers, air carriers should develop and implement automated aural or visual cabin	4.2	3.3	4.4	1.7

Int #	**INTERVENTIONS**	**P**	**C**	**A**	**Overall Effectiveness**
	alerting systems.				
620	To improve the accuracy of turbulence forecasts, air carriers and FAA should expand the forecasting techniques and CDM practices currently employed in the Strategic Planning Implementation Team and CCFP to turbulence forecasting.	4.6	3.4	3.7	1.6
629	To reduce injuries from inadvertent contact with service equipment (such as serving carts and hot beverage equipment), manufacturers, air carriers and FAA should test, redesign, and implement additional systems to secure service and equipment items, such as cart-restraint floor tracks or “mushrooms”, retractable arms, and sealed hot beverage containers.	4.8	3.9	2.9	1.5
630	To ensure passenger adherence, DOT and FAA and air carriers should continually promote seat belt usage and compliance with advisories and warnings by extending the “Vince and Larry” Seat Belt Campaign to aviation and by other public service initiatives (e.g. videos, airport signage and posters, ticket covers, napkins, brochures, web sites, etc.).	4.3	2.9	4.2	1.5
603	To ensure that passengers are aware of potential hazards, air carriers should develop and implement standardized pre-flight briefings to passengers (including multi-lingual briefings, as appropriate) that provide practical information about anticipated turbulence hazards and emphasize passenger responsibility for seat belt compliance	4.0	3.0	4.0	1.3
626	To reduce injuries from ineffective or failed restraint systems, air carriers and manufacturers should consider the redesign of such systems to ensure that flight attendants and passengers, including small children, are secure during turbulence.	4.4	3.6	2.6	1.1
611	To provide more flexibility in route selection to avoid turbulence in International Airspace, the FAA and other governmental agencies should establish additional transoceanic tracks.	4.3	3.2	2.9	1.1
615	To improve communication among providers and users of turbulence information, Government and industry should standardize ground and in-flight indications of turbulence hazard intensity and the phraseology used in dissemination, and should ensure that operators, flight crews, and ATC receive the same information.	4.1	3.4	2.7	1.0
627	To reduce injuries that result from overhead storage bins that open during turbulence encounters, manufacturers should evaluate and redesign, as applicable, storage bins and all other items suspended overhead from the ceiling.	4.6	3.1	1.9	0.8

APPENDIX K TURBULENCE INTERVENTION STRATEGIES
(Sorted by Category)

Recommendation 1: Improve the Use of Available Information

#	Intervention	P	C	A	OE
616	To support a primary strategy of turbulence avoidance, air carriers should implement "best practices," as outlined in FAA Advisory Circular AC00-30b. These practices should include, but not be limited to, establishing full meteorological capabilities in-house or through a vendor, the establishment of a turbulence charting and alerting program that identifies current risks and areas where turbulence and mountain waves are most common, etc.	5.4	4.9	5.3	3.9
613	To depict the best route of flight around turbulence, air carriers and manufacturers should develop and implement real-time graphical weather displays and turbulence alerts to the flight deck.	5.3	4.6	4.3	2.9
614	To provide clear detection and depiction of turbulence location and intensity, Government and industry should develop and implement methods to synthesize available airborne, ground-based and satellite data, forecasts, "nowcasts" and meteorological models.	5.0	4.1	4.5	2.6
617	To ensure that all users and service providers have real-time access to PIREPs and other time-critical weather information, government and industry should develop a capability to share such information.	5.0	4.1	4.1	2.3
608	To reduce inadvertent flight into turbulence associated with convection, industry and government should develop and implement separation standards that use visual cues and indications from on-board systems (such as radar, outside air temperature, etc).	4.7	3.8	4.5	2.2
610	To improve the effectiveness of flight planning and decision-making processes, government and industry should continue to develop collaborative decision making (CDM) and joint training programs in order to enhance effective CDM among dispatchers, meteorologists, ATC and flight crews, with emphasis on joint participation in flight planning, timely communication (including CPDLC, voice, etc.), in-flight decision making and ensuring that all functions share the same sources of weather information.	4.5	3.4	4.7	2.0
609	To better manage turbulence risks, air carriers should improve fundamental knowledge about meteorology and types of turbulence by providing adequate initial and recurrent training to flight crews, meteorologists and dispatchers in turbulence assessment, recognition and avoidance.	4.5	3.6	4.7	2.1
607	To assure availability of the most current and highest quality turbulence information, air carriers should audit their current systems for receiving, analyzing and disseminating weather products and ensure that dispatchers and flight crews effectively obtain and use all available turbulence information contained currently in SIGMETS, PIREPS and AIRMETS, and in Flight Watch and HIWAS services.	3.9	3.7	4.3	1.7

Recommendation 2: Improve Information about the Location and Severity of Turbulence

#	Intervention	P	C	A	OE
628	To detect and warn of imminent turbulence encounters, manufacturers, air carriers and Government should develop and implement an airborne, ground-based or satellite system that warns of impending turbulence immediately ahead of the aircraft.	5.2	4.2	5.2	3.2
621	To improve the collection and dissemination of objective real-time turbulence reports, air carriers and manufacturers should continue to develop and implement automatic methods for detecting turbulence encounters and reporting them electronically (along with other relevant weather information) to all users.	5.7	4.7	4.4	3.3
619	To make forecasts and warnings of turbulence and other hazardous weather more spatially and temporally precise, accurate and more applicable to specific routes and specific aircraft types and categories, Government, weather providers and the air carriers should improve the accuracy of those products.	5.5	4.0	4.7	2.9
618	To obtain more PIREPs in conformance with the AIM, pilots should report turbulence in the form of PIREPs to ATC (may be broken out to specific ATC elements.	5.0	3.7	3.9	2.0
612	To more accurately depict low reflectivity thunderstorms, manufacturers and air carriers should develop and implement improved detection equipment and associated operating procedures.	4.6	4.1	3.5	1.8
620	To improve the accuracy of turbulence forecasts, air carriers and FAA should expand the forecasting techniques and CDM practices currently employed in the Strategic Planning Implementation Team and CCFP to turbulence forecasting.	4.6	3.4	3.7	1.6

Recommendation 3: Improve Risk Management for Flight Attendants

#	Intervention	P	C	A	OE
622	To reduce flight attendants' exposure to turbulence, during climb and descent, air carriers should establish and implement a policy and related SOPs that require all flight attendants and passengers to be seated and restrained from takeoff to cruise altitude and from FL200 through landing.	5.5	4.8	4.9	3.6
623	To reduce flight attendants' exposure to turbulence while performing seat belt monitoring, FAA should require and air carriers should develop and implement clearly stated policies and standard operating procedures, to be included in flight attendant manuals, that allow cabin crew to prioritize, without repercussion, immediate duties and cabin service schedules, including the option to be seated while making seatbelt announcements in response to anticipated turbulence hazards or warnings.	5.0	4.4	4.4	2.7
624	To equip flight attendants with the insights and knowledge required to prioritize cabin duties versus the risk of turbulence injuries, FAA should require air carriers to develop and implement training for flight attendants in turbulence hazards, aircraft behavior in turbulence, and the need to ensure their own safety.	4.5	3.7	4.4	2.0

Recommendation 4: Improve Communications

#	Intervention	P	C	A	OE
601	To ensure effective cockpit-cabin communication, FAA should require that air carriers' operating specifications and training programs include standardized procedures and phraseology for pre-flight and in-flight	4.4	4.9	4.8	2.9

	communication of turbulence hazards, degree of hazard and all clear declarations.				
602	To improve the timeliness and effectiveness of turbulence warning dissemination and damage reports, air carriers should develop and implement instant two-way communications capability between cabin crew and flight crew anywhere in the aircraft at all times.	4.0	4.0	4.0	1.8
604	To gain compliance by passengers who otherwise ignore seating or seat belt instructions, air carriers and Government should develop and implement enforcement policies and procedures on how to deal with passengers' who do not heed warnings.	4.0	4.0	4.0	1.8
605	To provide immediate warning to the cabin crew and passengers, air carriers should develop and implement automated aural or visual cabin alerting systems.	4.2	3.3	4.4	1.7

APPENDIX L GLOSSARY OF ACRONYMS AND DEFINITIONS

Turbulence JSAT

Definitions:

Accident	Occurrence associated with the operation of an aircraft which takes place between the time any person boards the aircraft with the intention of flight and until such time as all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.
Applicability	A component of Overall Effectiveness. Applicability relates to how frequently the problem(s) being addressed by the intervention will continue to be present on a widespread basis in future operations (nominally, circa 2007).
Characteristics & Indicators	A set of information about each accident/incident obtained from the accident report or other publicly available information. Each JSAT (1) uses the C&Is developed from a prior JSAT; (2) develops a completely new set of C&Is; or uses a combination of previously developed and new C&Is.
Clear Air Turbulence	Turbulence that occurs in the optically clear air; not in clouds.
Confidence	A component of Overall Effectiveness. Confidence deals with how strongly we believe that everyone/everything will perform as expected. The Confidence factor brings in an assessment of the real world, where interventions do not always have the desire effect.
Contributing Factors	Identify factors both in the crew's environment and personal factors are why an inappropriate response or latent failure occurred.
Convective-Induced Turbulence	Turbulence that occurs during the penetration of a convective cell (e.g. thunderstorm) or turbulence that occurs in the horizontal vicinity of, or above a convective cell (e.g. convectively-induced gravity wave).
Data Driven	Decisions, results and recommendations that are supported by, rooted in, and traceable to data (accident/incident reports, FOQA data, prior studies, etc.). Expert opinions that are logical, structured and traceable to data will also be used.
Effectiveness	Prioritization of the intervention strategies based on the breadth and depth of their relative potential for preventing accidents.
Events	Describe, relative to a time mark, the actions taken or omitted by the crew, the conversations of the crew and between the crew and ATC, and the airplane maneuvers prior to the accident.

Feasibility	Current potential for implementation of the intervention strategies on a widespread basis.
Flight Attendant/Cabin Crew	Crew member who has met the necessary training and qualification standards and who is assigned to the cabin.
Flight Crew	Pilot airline personnel whose primary area of work is in the flight deck of the aircraft.
Implementation	How to incorporate a given intervention strategy.
Incident	Occurrence associated with the operation of an aircraft, which takes place between the time any person boards, the aircraft with the intention of flight and until such time as all such persons have disembarked, and in which any person suffers minor injuries or the aircraft receives minor damage.
Intervention Strategies	Proposed activity intended to prevent or mitigate a given safety-significant problem associated with the cause of an accident.
Minor Injury	Any injury which is less than the criteria for a serious injury.
Mechanical Turbulence	Turbulence produced by the interruption of airflow over such obstructions as buildings, trees and rough or mountainous terrain.
Mountain Wave Turbulence	Turbulence that occurs above or downwind of mountainous terrain, either in the strong updrafts associated with a wind-driven wave, or by the rapidly spinning rotor found downwind at any altitude.
Overall Effectiveness	A calculated combination of Power, Confidence, and Applicability scores, which is intended to estimate how effective an intervention is likely to be in preventing future accidents.
Overall Effectiveness Rank	The order of intervention strategies, relative to all other intervention strategies, after the Overall Effectiveness has been calculated and the Overall Effectiveness Scores have been ordered numerically.
Overall Effectiveness Score	The score that results from the calculated combination of Power, Confidence, and Applicability, using the formula, OE = P x C/6 x A/6.

Part (119) (121) (135)	The section of the Code of Federal Regulations (CFR) that applies to specific types of airline operations, i.e 14 CFR 135 refers to "Operating Requirements: Commuter and On Demand Operations and Rules Governing Persons on Board Such Aircraft". Part 119 is "Air Carriers and Operators for Compensation or Hire", and Part 121 is Domestic, Flag, and Supplemental Operations".
Power	A component of Overall Effectiveness. Power relates to how well the intervention directly and definitively addresses the problem/contributing factors in the accident, and by doing so, would have reduced the likelihood of the accident, if everyone/everything performed as the intervention intended.
Problem Statements	Describe what went wrong, define a deficiency, or describe a potential reason some action occurred or did not occur. They represent inappropriate crew responses, latent failures in organizational management and/or regulatory agency oversight. They may also reflect active failures by maintenance.
Serious Injury	Any injury which (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date an injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes or nose); (3) causes severe hemorrhages, or nerve, muscle, or tendon damage; (4) involves any internal organ; or (5) involves second- or third-degree burns, or any burns affecting more than 5 percent of the body surface.
Terrain-Induced Turbulence	Turbulence that is caused generally by windflow over precipitous terrain that is not mountainous (low hills, valleys, etc.).
Turbulence	Any rapidly changing wind that when encountered by an aircraft in flight, causes rapid fluctuations in airspeed or altitude in the order of a few seconds or less, thus causing discomfort to passengers to crew, ranging from inconvenience, to injury, death, and damage and loss of aircraft in the extreme.
Wake Turbulence	Turbulence resulting from the passage of an aircraft through the atmosphere. As pressure Includes vortices, thrust stream turbulence, jet blast, jet wash, propeller wash, and rotor wash both on the ground and in the air.

Acronyms:

AC	Advisory Circular
ADF	Airline Dispatchers Federation
AFA	Association of Flight Attendants
AIRMET	Airman's Meteorological advisory (WA)

ALPA	Air Line Pilots Association
AOC	Airline Operations Center
APA	Allied Pilots Association
APFA	Association of Professional Flight Attendants
ASRS	Aviation Safety Reporting System
|ATA	Air Transport Association
ATC	Air Traffic Control
CAST	Commercial Aircraft Safety Team
CAT	Clear Air Turbulence
CCFP	Collaborative Convective Forecast Product
CDM	Collaborative Decision Making
DOD	Department of Defense
FAA	Federal Aviation Administration
FAA/AAI	Federal Aviation Administration/Accident Investigation
FAA/AAR	Federal Aviation Administration/Aviation Research
FAA/AFS	Federal Aviation Administration/Aviation Flight Standards
FAA/ASY	Federal Aviation Administration/Systems Safety
FAA/ATP	Federal Aviation Administration/Air Traffic Planning and Procedures
FAA/ARW	Federal Aviation Administration/Aviation Weather Requirements
FAA/CAMI	Federal Aviation Administration/Civil Aeromedical Institute
FOQA	Flight Operations Quality Assurance
HIWAS	High Altitude Weather Advisory Service
IAM	International Association of Machinists
JSAT	Joint Safety Analysis Team
JSIT	Joint Safety Implementation Team
MIT LL	Massachusetts Institute of Technology – Lincoln Laboratories
NAATS	National Association of Air Traffic Specialists
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NCAR	National Center for Atmospheric Research
NOAA	National Oceanic and Atmospheric Administration
NRL	Naval Research Laboratory
NTSB	National Transportation Safety Board
OE	Overall Effectiveness
OER	Overall Effectiveness Rank
OES	Overall Effectiveness Score
PCA	Power, Confidence, Applicability
PIREP	Pilot Report
SIGMET(WS)	Significant Meteorological advisory
UCAR	University Corporation for Atmospheric Research

APPENDIX M BIBLIOGRAPHY

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