Wake & Weather Turbulence Report
February 2016

Federal Aviation Administration

AVP–210

Wake & Weather Turbulence Report

February 2016

Office of Accident Investigation and Prevention
Safety Analysis Branch, AVP–210
800 Independence Avenue SW
Room 835
Washington, DC 20591

THIS PAGE INTENTIONALLY LEFT BLANK

Table of Contents

THIS PAGE INTENTIONALLY LEFT BLANK

List of Figures and Tables

Executive Summary

2,983 weather-related aviation accidents occurred from 2002 to 2013. Of these 2,983 accidents, 182 were cited as turbulence events, 38 of which were fatal. Wake turbulence is not included in these numbers.

Over the same 12-year period, most of the 222 aircraft involved in wake and weather turbulence accidents operated under Title 14, Code of Federal Regulations Part 91 (104 aircraft) or Part 121/135 (97 aircraft). Additionally, 89% of the 38 fatal turbulence accidents occurred in Part 91 operations, whereas no fatal turbulence accidents occurred in Part 121 operations.

THIS PAGE INTENTIONALLY LEFT BLANK

Introduction

This report reviews National Transportation Safety Board (NTSB) accident data from 2002 to 2013 in which turbulence was a cause or contributing factor. The analysis staff in the Office of Accident Investigation and Prevention, Data and Analysis Branch (AVP–210), which is part of the Federal Aviation Administration's (FAA) Office of Aviation Safety, wrote this report as an update to "Review of Aviation Accidents Involving Weather Turbulence in the United States, 1992–2001," a 2004 report by the National Aviation Safety Data Analysis Center (NASDAC).

Data Source – NTSB

This report uses accident data reported in the NTSB Aviation Accident/Incident Data System, as hosted in the FAA Aviation Safety Information Analysis and Sharing (ASIAS) System. The NTSB is the official U.S. Government custodian of aviation accident data and causal factors. It is an independent federal agency, and not part of the FAA's parent organization, the U.S. Department of Transportation.

The NTSB database (part of the NTSB Aviation Accident/Incident Data System) contains information about events—accidents and incidents—derived from their investigations. Although most accident and incident reports are finalized in two or three years, this process can take up to five years. This report focuses only on accidents; the NTSB defines an accident as an event associated with the operation of an aircraft that takes place between the time any person boards the aircraft with the intention of flight and all such persons have disembarked, and in which any person suffers death or serious injury or in which the aircraft receives substantial damage.

The NTSB's data system includes preliminary, factual, and probable cause reports. Generally, a preliminary report of the facts is available online within a few days of an event. Additional factual information is added as it becomes available, and when the investigation is completed, the factual and probable cause reports replace the preliminary reports. The factual report is the final description of the accident, and the probable cause report is the NTSB's assessment of why the accident occurred, citing causes and contributing factors.

The NTSB's accident data is organized around events, aircraft, occurrences, and findings, and is stored in a database that supports the written reports.

- Event records describe the attributes of the accident or incident shared by all of the aircraft involved, including place, time, weather, and severity.
- Aircraft records describe attributes of the specific aircraft involved in the event, such as make, model, engine, certification, and type of flight.
- Occurrence records describe the happenings that occurred leading up to the event or that resulted from the event. Occurrence records are factual, and most are reported before release of the factual report. Fire, forced landing, and loss of control are examples of occurrences.
- Finding records describe the causes and contributing factors for each aircraft involved in the event, for example, terrain-induced turbulence.

The organization of the NTSB database means for a given event, there can be more than one aircraft, and for each aircraft, there are generally multiple occurrences and multiple causes and contributing factors reported.

The NTSB made changes to its database in 2008 that affected the way occurrences are related to findings. Before 2008, each occurrence potentially could be found to be a cause or contributing factor; that is, occurrences and findings were linked by the unique occurrence number. The changes in 2008 severed that linkage and rewrote the list of possible occurrences. In both cases, occurrences are drawn from lists that broadly describe what occurred. The Commercial Aviation Safety Team (CAST)/International Civil Aviation Organization (ICAO) Common Taxonomy Team (CICTT) has defined a similar list that is intended to be used by all aviation parties, but the occurrences in the NTSB database do not align with the CICTT list. Appendix B to this report reviews the pre- and post-2008 NTSB occurrence lists and compares them with the CICTT list.

The NTSB also restructured its accident causal codes during the 2008 database changes. Subsequently, some of the post-2008 codes do not map directly to the pre-2008 codes. To account for this change, the analysts used the post-2008 codes and mapped the pre-2008 codes to the extent practicable. The map is shown in Figure 1.

This report did not use pre-2008 codes for Updraft and Downdraft, because they were mapped to the Wind subcategory, rather than the Turbulence subcategory, in the post-2008 scheme. Similarly, Mountain Wave, Turbulence in Clouds, and Turbulence (Thunderstorms) were not used because there was no connection to the new Turbulence subcategory.

Report Organization

The first section of this report, I: Weather and Weather Turbulence Event Comparison, compares weather turbulence to all weather by event rather than by aircraft. As a result, the numbers reported are slightly lower than in a comparison by aircraft because more than one aircraft can be involved in an NTSB event. (Note: Wake turbulence was not included in the weather comparison.)

The second section, II: Turbulence (Wake and Weather) Review by Flight Operating Rule, reviews turbulence-related aircraft accidents across factors such as type of operation, phase of flight, and injury. As a result the analysts used aircraft data and, in a few cases, citation of turbulence findings or occurrences. Wake turbulence is included in this section.

With the count of events, aircraft, and citations differing, it is important to remain mindful of which data type was used for each result. This report uses the terms “event,” “aircraft,” or “citation” in every chart and title.

Data Criteria

This report used data extracted in February 2016 from the NTSB database in ASIAS that met the following considerations:

1. The event was rated an accident, rather than incident.
2. In section I, weather and weather turbulence events occurred in the United States.
3. In section II, the aircraft operated under Title 14, Code of Federal Regulations (14 CFR) Part 91, Part 121, Part 133, Part 135, Part 137, or Part 129; or as Public Use or Non-U.S. Commercial.
4. The citation was a cause or contributing factor for finalized events.
5. Events from 2002 through 2007 had only the codes listed in the left column of Figure 1.
6. Events from 2008 through 2013 had only the codes listed in the "Final" column of Figure 1, or when no final code existed, the codes listed in the "Factual" column of Figure 1.

Table 1. Turbulence Codes in NTSB Database as Identified Before and After 2008

Pre-2008			2008-Current		
				Final	***Factual***
Subject_ Modifier_Code	**Subject_Modifier**		**Subsection**	**Finding_Code**	**EventSOE_nbr**
2224	Turbulence	⇔	(General)	0303200081	360
2253	Turbulence, Terrain-Induced	⇔	Terrain-Induced Turbulence	0303201081	
2225	Turbulence, Clear Air	⇔	Clear Air Turbulence	0303201581	362
2256	Turbulence, Convection Induced	⇔	Convective Turbulence	0303202081	
Subject_Code	**Subject**				
24715	Wake Turbulence	⇔	Wake Turbulence	0303202581	361

THIS PAGE INTENTIONALLY LEFT BLANK

I. Weather and Weather Turbulence Event Comparison

Accident Event Comparison – Twelve-Year Review

According to the NTSB, 19,575 aviation accidents occurred in the United States from 2002 to 2013. During this timeframe, weather was identified as a cause or contributing factor in 2,983 accidents. Of these, turbulence was a cause or contributing factor in 182 accident events (6.1% of the population). Figure 1 depicts the 12-year accident count, which compares non-turbulence weather events (2,801) to turbulence events (182).

Figure 1. Comparison of Weather Events to Weather Turbulence Events

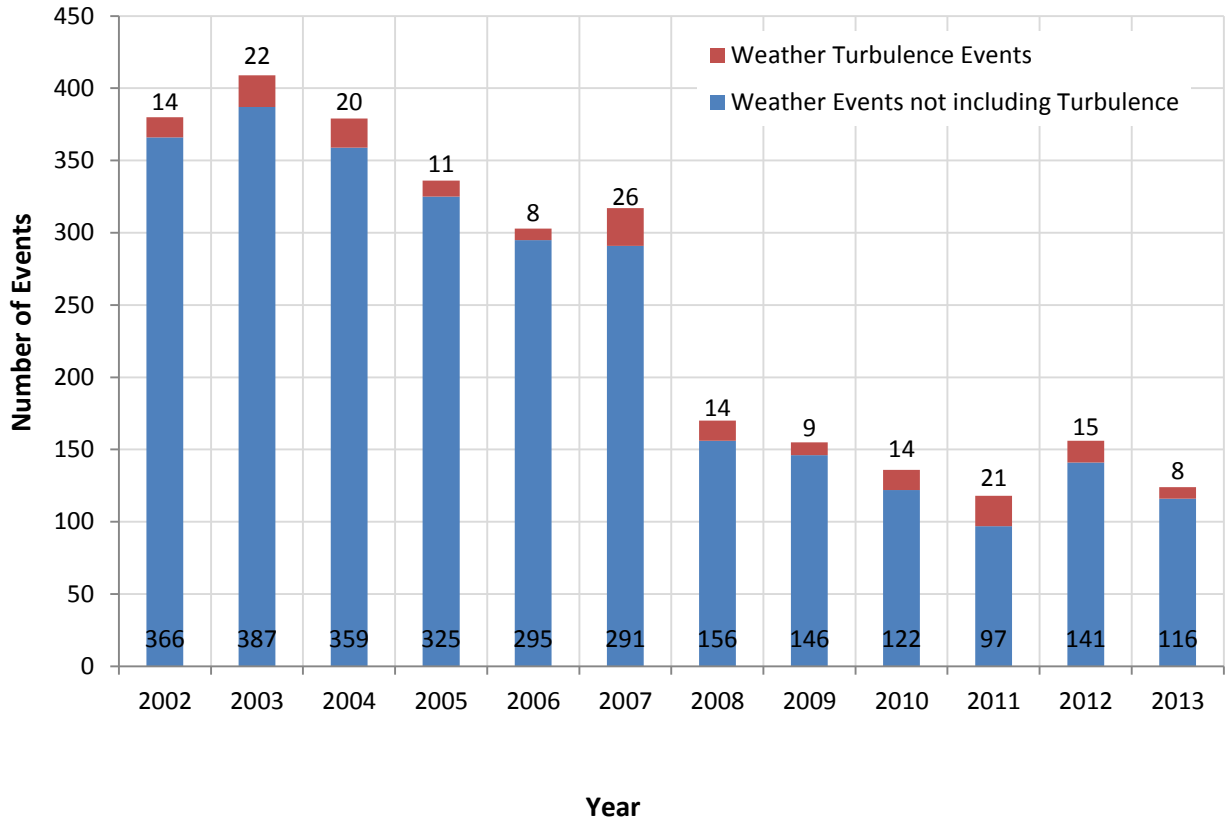


Table 2. Percentage of Weather Turbulence Events to Weather Events

Year	Weather Accidents	Weather Turbulence Accidents	Percent Turbulence
2002	380	14	3.6%
2003	409	22	5.1%
2004	379	20	5.0%
2005	336	11	3.2%
2006	303	8	2.6%
2007	317	26	7.6%
2008	170	14	7.6%
2009	155	9	5.5%
2010	136	14	9.3%
2011	118	21	15.1%
2012	156	15	8.8%
2013	124	8	6.1%
Total	**2983**	**182**	**6.1%**

Figure 2 and Table 3 show a breakout of the type of weather citations in the 2,983 events. These events include a total of 897 weather citations, including 72 turbulence citations, which is just over 8% of the total weather citations. Because each event could have more than one weather citation, the number of events in this table will not match previous weather event counts.

Figure 2. Total Weather Citations by Phenomenon

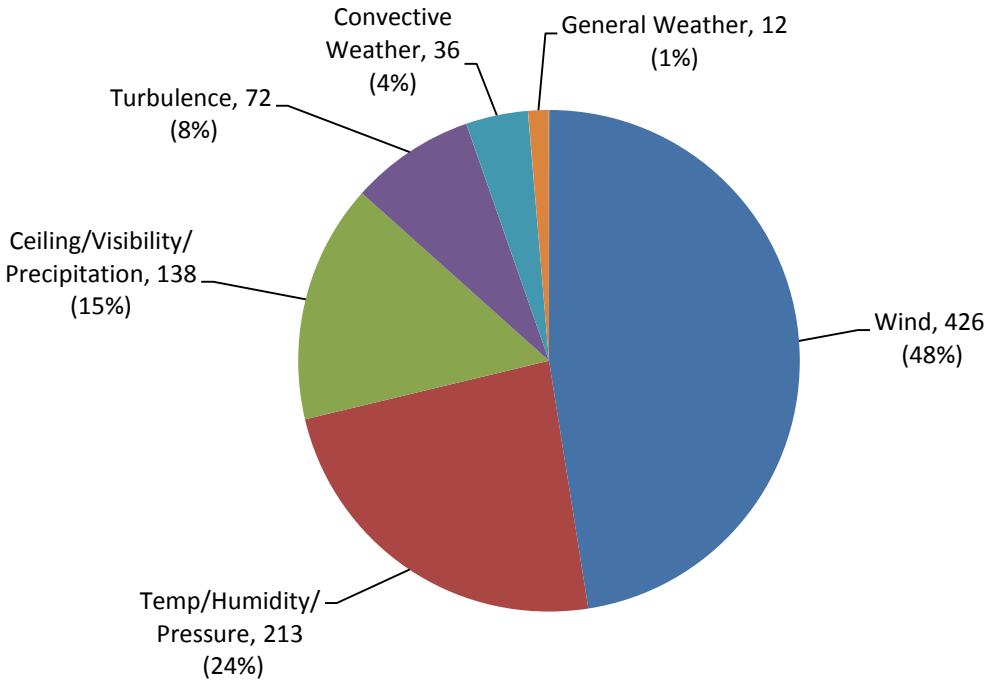


Table 3. Total Weather Accident Citations by Phenomenon

Weather Category	Event Count
Wind	426
Temp/Humidity/Pressure	213
Ceiling/Visibility/Precipitation	138
Turbulence	72
Convective Weather	36
General Weather	12
Total	**897**

Accident Event Comparison – Injury Review

As shown in Table 4, 38 fatal weather-related events occurred from 2002 to 2013, of which 59 (5.4%) involved turbulence. Table 5 depicts the 1,345 weather-related fatalities, of which 84 (6.2%) involved turbulence.

Table 4. Percentage of Fatal Weather Events to Fatal Weather Turbulence Events

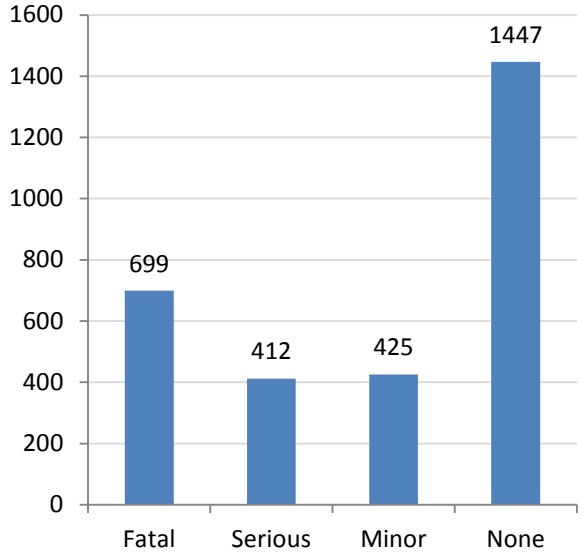
Year	Fatal Weather Events (Including Turbulence)	Fatal Turbulence Events	Percent of Fatal Weather Events Due to Turbulence
2002	89	3	3.4%
2003	105	4	3.8%
2004	98	6	6.1%
2005	71	3	4.2%
2006	77	2	2.6%
2007	71	9	12.7%
2008	51	3	5.9%
2009	23	0	0.0%
2010	21	3	14.3%
2011	22	2	9.1%
2012	34	2	5.9%
2013	37	1	2.7%
Total	**699**	**38**	**5.4%**

Table 5. Percentage of Weather Fatalities to Weather Turbulence Fatalities

Year	Weather Fatalities (Including Turbulence)	Turbulence Fatalities	Percent Turbulence Fatalities
2002	151	5	3.3%
2003	210	8	3.8%
2004	194	12	6.2%
2005	137	9	6.6%
2006	148	5	3.4%
2007	151	25	16.6%
2008	98	5	5.1%
2009	43	0	0.0%
2010	37	6	16.2%
2011	51	2	3.9%
2012	51	3	5.9%
2013	74	4	5.4%
Total	**1345**	**84**	**6.2%**

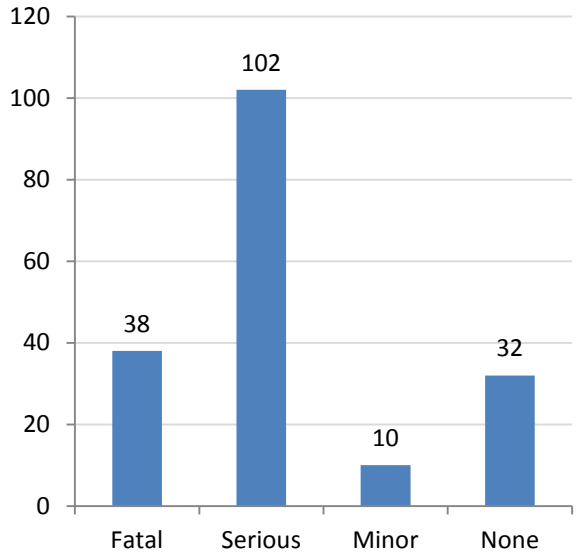
Figures 3 and 4 depict the distribution of worst injury aboard for accidents caused by weather and turbulent weather from 2002 to 2013.

Figure 3. Weather Events by Worst Injury Aboard



Severity of Worst Injury Aboard	Number of Weather Events	Percent
Fatal	699	23.4%
Serious	412	13.8%
Minor	425	14.2%
None	1447	48.5%
Total	**2983**	**100.0%**

Figure 4. Weather Turbulence Events by Worst Injury Aboard



Severity of Worst Injury Aboard	Number of Weather Turbulence Events	Percent
Fatal	38	20.9%
Serious	102	56.0%
Minor	10	5.5%
None	32	17.6%
Total	**182**	**100%**

The data indicates that as a percentage, weather turbulence resulted in serious injuries more often than all weather accidents (56.0% versus 13.8%).

THIS PAGE INTENTIONALLY LEFT BLANK

II. Turbulence (Wake and Weather) Review by Flight Operating Rule

According to the NTSB, 21,593 aircraft were involved in accident events from 2002 to 2013. Of those, 222 were involved in wake or weather turbulence accidents. None of these events involved more than one aircraft; therefore, the number of wake and weather turbulence events is also 222.

The 222 aircraft involved in turbulence accidents operated under a variety of 14 CFR parts in which the FAA has established the rules for various types of flight operations, including—

- Part 91 – General aviation (recreational, training, fractional ownership, etc.).
- Part 121 – Scheduled air carriers and cargo carriers that fly large transport-category aircraft.
- Part 129 – Foreign air carriers.
- Part 133 – Rotorcraft carrying external loads.
- Part 135 – Scheduled or nonscheduled air taxi operations (nine or fewer passengers).
- Part 137 – Agricultural aircraft operations.
- Public Use – Includes federal, state, and local public use.
- Non-U.S. Commercial.

The majority of the turbulence accidents occurred during Part 91 and Part 121 operations, as depicted in Table 6.

Table 6. Aircraft Involved in Turbulence and Fatal Turbulence by Operation

14 CFR Part	Aircraft Involved in Fatal Turbulence	Aircraft Involved in Turbulence	Percentage Fatal
Part 91	39	104	37.5%
Part 121	0	91	0.0%
Part 129	2	6	33.3%
Part 135	3	6	50.0%
Part 137	0	5	0.0%
Non-U.S. Commercial	0	5	0.0%
Public Use	0	3	0.0%
Unknown	0	2	0.0%
Part 133	0	0	0.0%
Total	**44**	**222**	**19.8%**

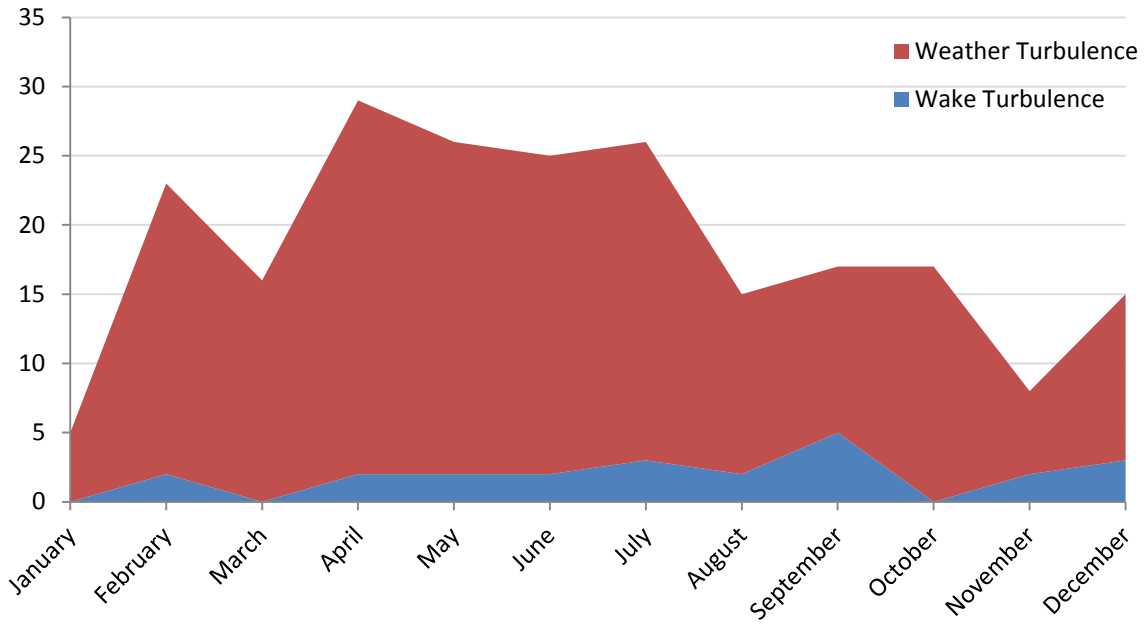
Similarly, the majority of wake turbulence accidents occurred during Part 91 operations. Table 7 depicts the distribution of turbulence accidents between wake turbulence and weather turbulence.

Table 7. Aircraft Involved in Weather and Wake Turbulence by Operation

14 CFR Part	Aircraft Involved in Wake Turbulence	Aircraft Involved in Weather Turbulence	Total Aircraft Involved in Turbulence	Percent of Aircraft Involved in Wake Turbulence
Part 91	19	85	104	18.3%
Part 121	1	90	91	1.1%
Public Use	1	5	6	16.7%
Part 135	0	6	6	0.0%
Part 129	0	5	5	0.0%
Part 137	2	3	5	40.0%
Unknown	0	3	3	0.0%
Non-U.S. Commercial	0	2	2	0.0%
Part 133	0	0	0	0.0%
Total	**23**	**199**	**222**	**10.4%**

Figure 5 shows the distribution of aircraft involved in weather and wake turbulence accidents by month for the 12-year period from 2002 to 2013.

Figure 5. Aircraft Involved in Weather and Wake Turbulence Accidents by Month

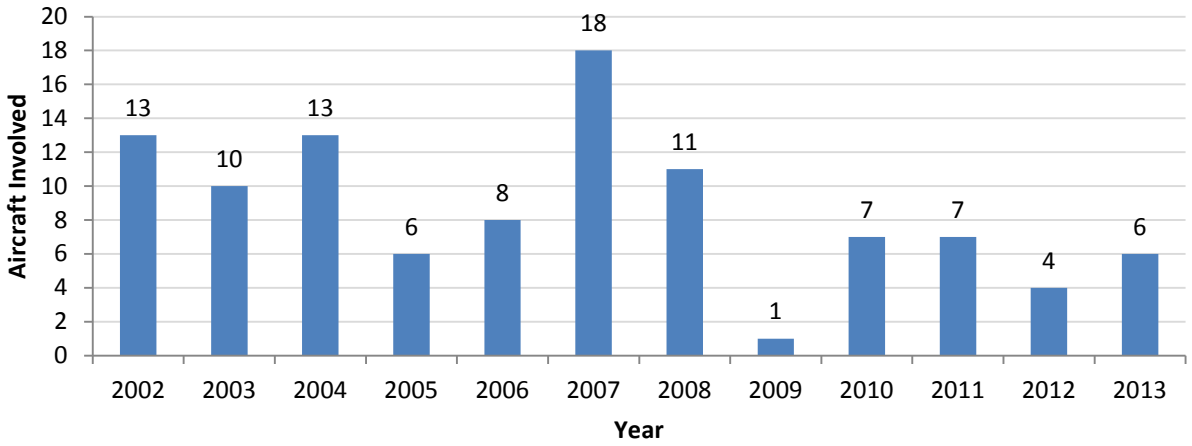


14 CFR Part 91 – Flight Operations Review

Part 91 prescribes rules governing the operation of aircraft (other than moored balloons, manned rockets, and unmanned free balloons, which are governed by Part 101, and ultralight vehicles operated in accordance with Part 103) within the United States, including the waters within three nautical miles of the U.S. coast. Flights operating for recreation and training are generally carried out under Part 91.

From 2002 to 2013, NTSB final reports identified turbulence as a cause or contributing factor in accidents involving 222 aircraft, including 104 aircraft operating under Part 91. Figure 6 shows the number of Part 91 aircraft accidents coded with a turbulence cause or contributing factor over the 12-year period.

Figure 6. Aircraft Involved in Turbulence Accidents by Year



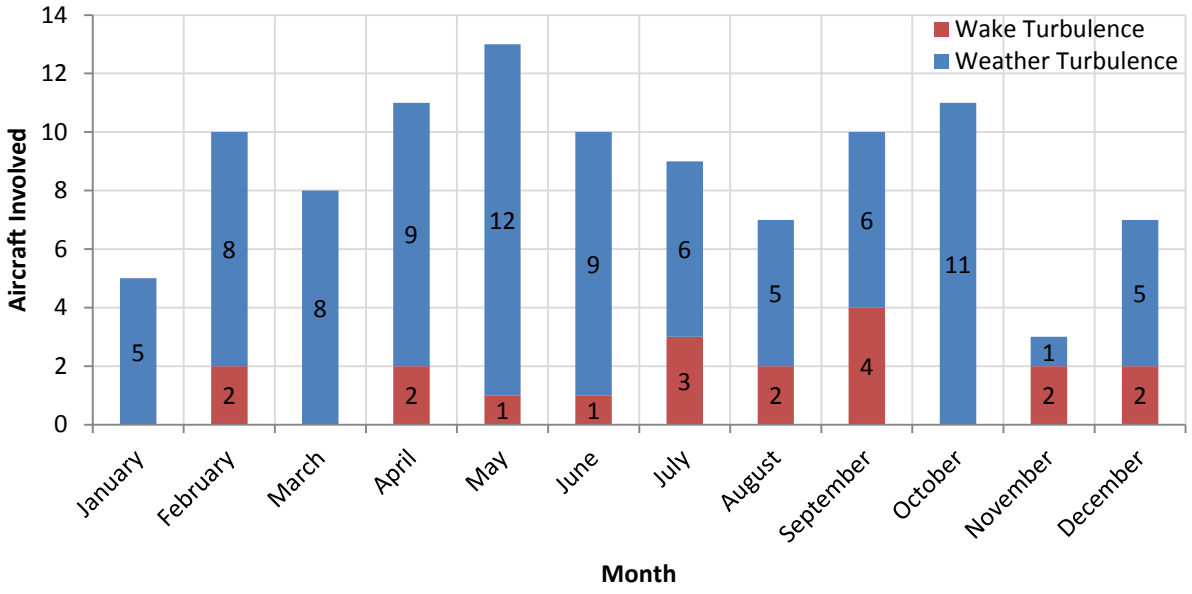
Part 91 operations can be classified further by the specific use of the aircraft for the individual flight. The majority of the turbulence events involving Part 91 operations were flights for personal use.

Table 8. Part 91 Aircraft Involved in Turbulence Aircraft Accidents by Use

Aircraft Use	Aircraft Involved
Personal	80
Positioning	6
Business	5
Air Race/Show	4
Instructional	3
Executive/Corporate	2
Flight Test	1
Public Use	1
Air Drop	1
Ferry	1
Total	**104**

There is a noticeable decrease in aircraft involved in turbulence accidents in the winter months, with November, December, and January rates below the monthly average of 8.6 accident aircraft.

Figure 7. Part 91 Aircraft Involved in Turbulence Accidents by Month



In the United States, California was the site of the greatest number of turbulence events involving part 91 operations. In 18.3% of events in which turbulence was a cause or contributing factor, terrain was also a cause or contributing factor. Table 9 highlights the locations of these events.

Table 9. Part 91 Aircraft Involved in Turbulence Accidents by State

State	Aircraft Involved	State	Aircraft Involved
*California	17	Indiana	1
*Colorado	9	Oregon	1
*Arizona	8	*Idaho	1
*Alaska	5	*Utah	1
*Washington	5	Virginia	1
Florida	4	*West Virginia	1
*New Mexico	4	Minnesota	1
Arkansas	4	Georgia	1
Texas	3	Maine	1
Tennessee	3	New York	1
*Wisconsin	3	*Wyoming	1
*North Carolina	3	*Michigan	0
*Oklahoma	3	*Illinois	0
*Nevada	2	Maryland	0
*Pennsylvania	2	Vermont	0
Missouri	2	Connecticut	0
South Carolina	2	Delaware	0
Iowa	2	Louisiana	0
Alabama	2	Massachusetts	0
Hawaii	2	Mississippi	0
*Kansas	2	Nebraska	0
*Kentucky	2	New Hampshire	0
Ohio	2	North Dakota	0
*Montana	1	Rhode Island	0
New Jersey	1	South Dakota	0
		Total	**104**

* These states include terrain-induced turbulence as a cause or contributing factor.

In Part 91 operations, the most common result of turbulence events is substantially damaged aircraft, even when the passengers and/or crew sustain no injuries.

Figure 8. Part 91 Aircraft Involved in Turbulence Accidents by Damage and Worst Injury Aboard

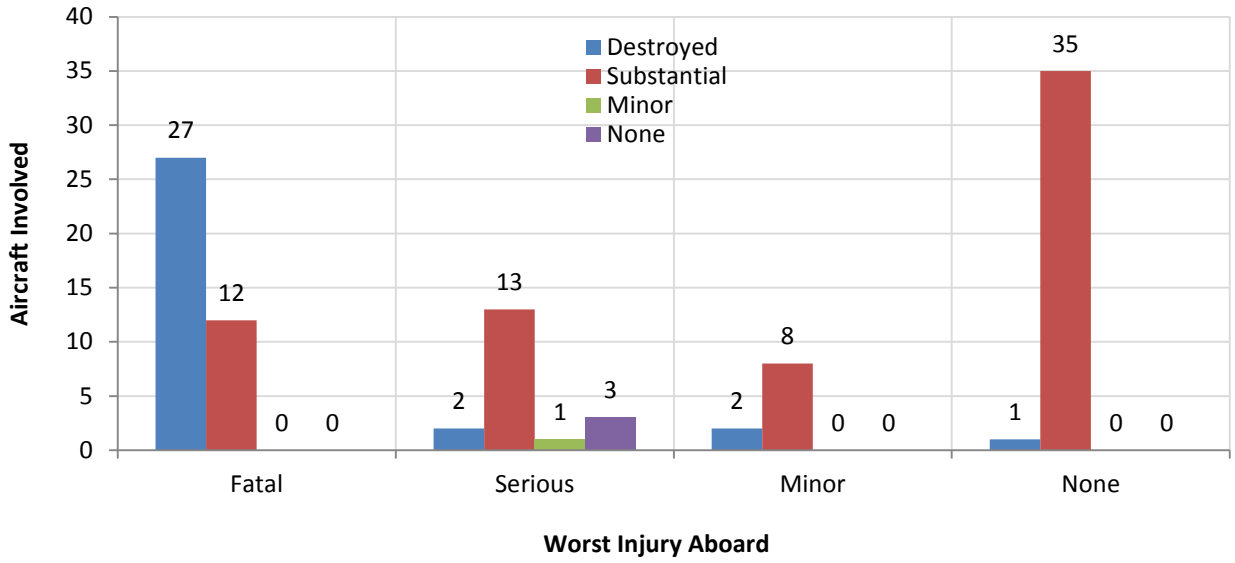


Table 10. Part 91 Aircraft Involved in Turbulence Accidents Aircraft by Damage and Worst Injury Aboard

Aircraft Damage	Fatal	Serious	Minor	None	Total
Destroyed	27	2	2	1	32
Substantial	12	13	8	35	68
Minor	0	1	0	0	1
None	0	3	0	0	3
Total	**39**	**19**	**10**	**36**	**104**

Between 2002 and 2013, 104 accidents involving part 91 aircraft occurred across five types of turbulence, resulting in 198 injury citations. Figure 9 shows the injury citations for each turbulence type. General turbulence is most commonly cited in all types of accidents involving injury, comprising 44% of all accidents included.

Figure 9. Part 91 Turbulence Citations by Turbulence Type and Injuries Aboard

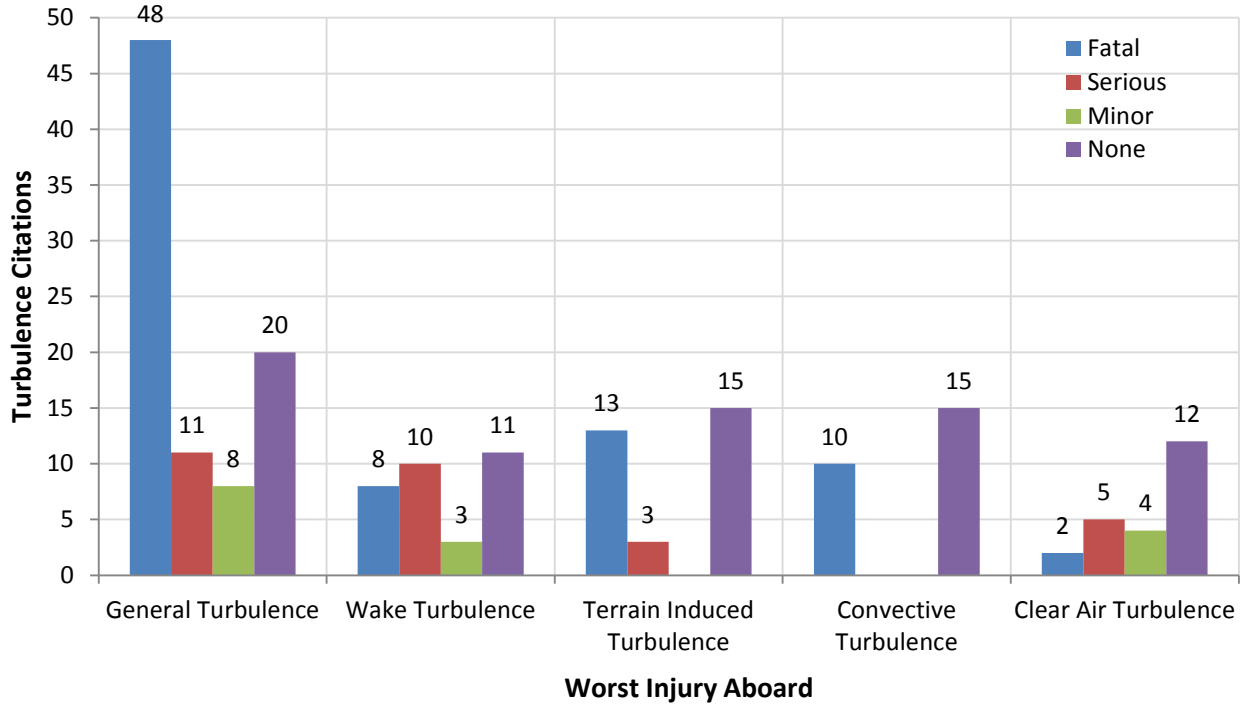


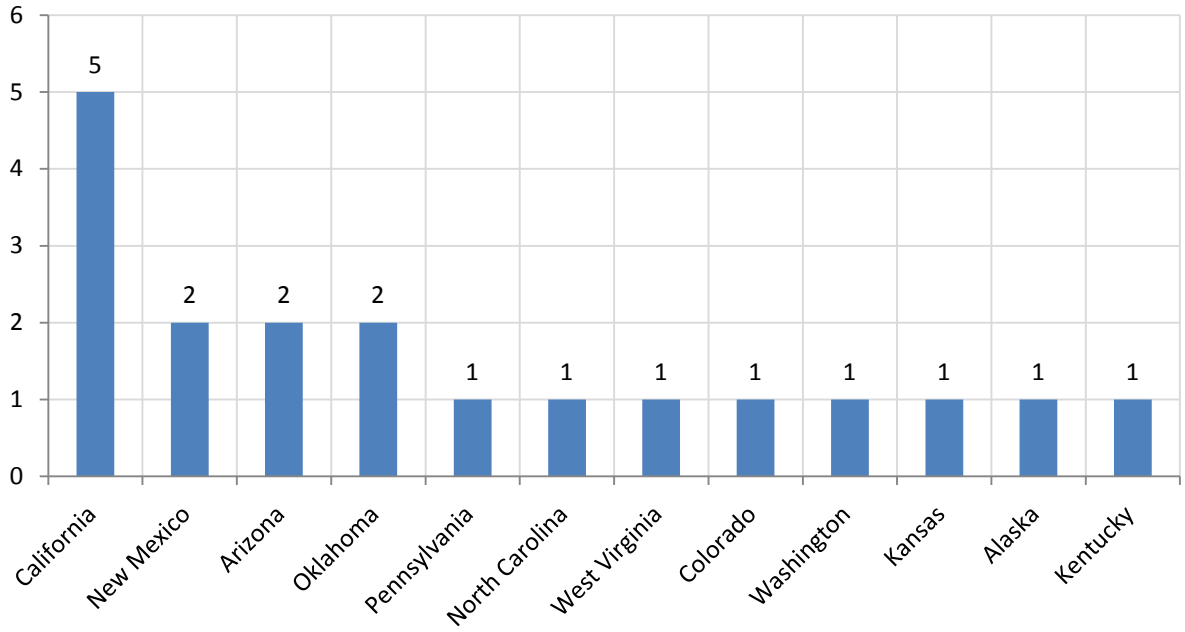
Table 11. Part 91 Turbulence Citations by Turbulence Type and Injuries Aboard

Turbulence Type	Fatal	Serious	Minor	None	Total
General Turbulence	48	11	8	20	87
Wake Turbulence	8	10	3	11	32
Terrain-Induced Turbulence	13	3	0	15	31
Convective Turbulence	10	0	0	15	25
Clear Air Turbulence	2	5	4	12	23
Total	**81**	**29**	**15**	**73**	**198**

In examining the breakout of the turbulence types for Part 91 aircraft accidents, it is interesting to note that fatal injuries outnumber all other injury types at 40.9% of injury citations, followed closely by no-injury accidents at 36.9% of citations. However, wake turbulence fared slightly better than the overall fatality percentage, with 25.0% of citations being fatal.

The terrain-induced turbulence accidents involving Part 91 aircraft occurred in the states shown below.

Figure 10. Part 91 Terrain Induced Turbulence Citations by State



The accidents involving Part 91 aircraft operations occurred during the phases of flight shown in the next three figures. Figure 11 shows that nearly half of fatalities occurred during cruise or approach.

Figure 11. Part 91 Fatal Turbulence Citations by Phase of Flight

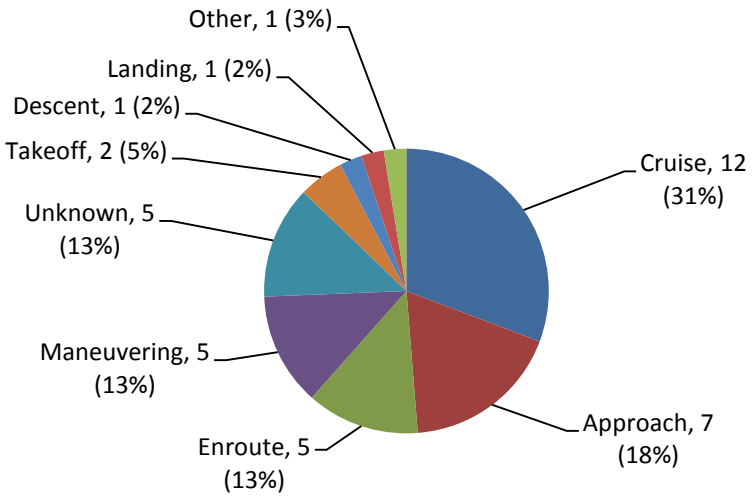


Figure 12. Part 91 Turbulence Citations by Phase of Flight and Worst Injury

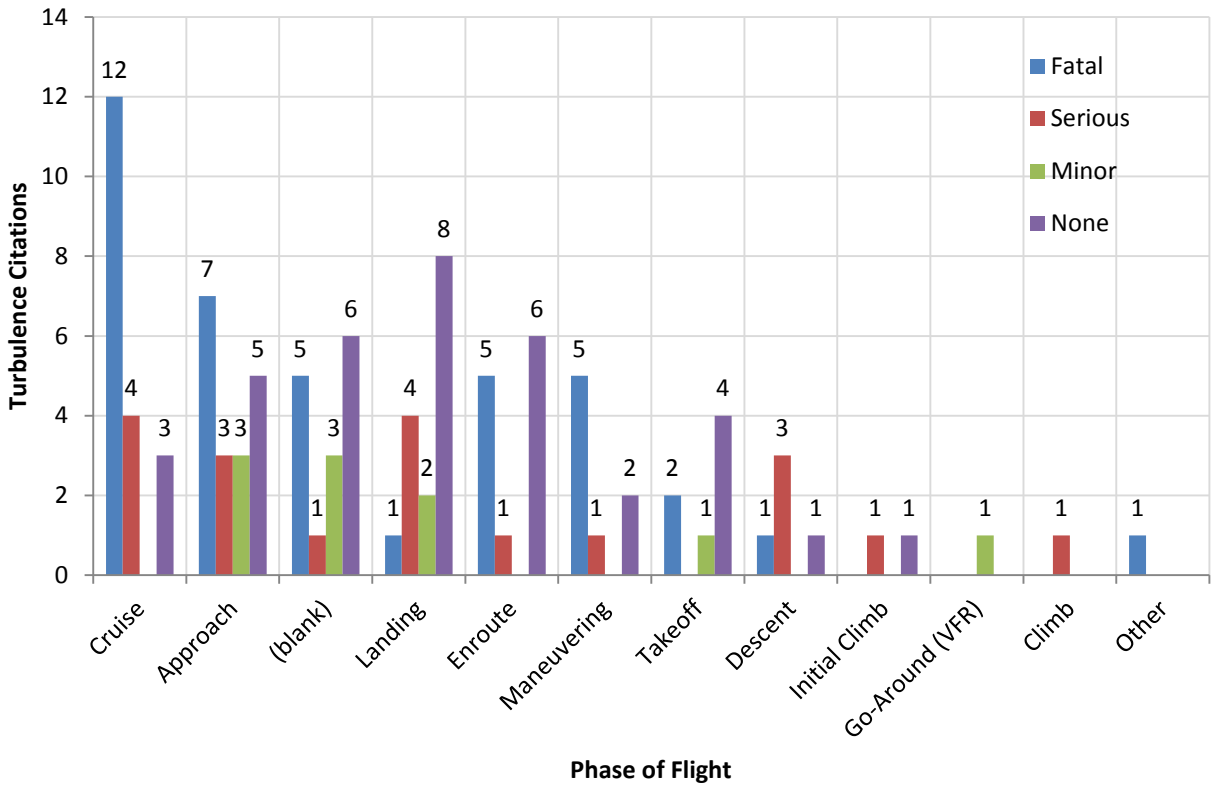


Table 12. Part 91 Turbulence Citations by Phase of Flight and Worst Injury

Phase of Flight	Fatal	Serious	Minor	None	Total
Cruise	12	4		3	19
Approach	7	3	3	5	18
Unknown	5	1	3	6	15
Landing	1	4	2	8	15
En Route	5	1	0	6	12
Maneuvering	5	1	0	2	8
Takeoff	2	0	1	4	7
Descent	1	3	0	1	5
Initial Climb	0	1	0	1	2
Go-Around (VFR)	0	0	1	0	1
Climb	0	1	0	0	1
Other	1	0	0	0	1
Total	**39**	**19**	**10**	**36**	**104**

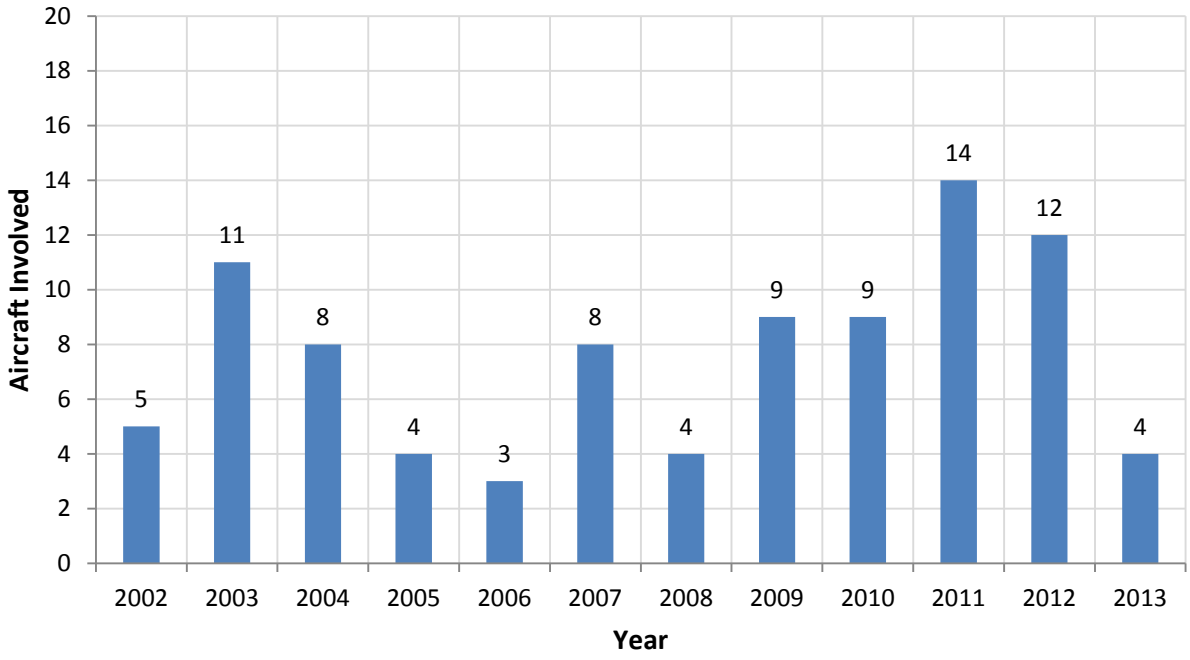
14 CFR Part 121 – Air Carrier Review

Part 121 refers to domestic airlines and cargo carriers that fly large transport category aircraft.

From 2002 to 2013, NTSB final reports identified turbulence as a cause or contributing factor in accidents of 222 aircraft, including 91 aircraft operating under Part 121.

Over this 12-year period, there was an annual average of 7.6 Part 121 aircraft accidents with turbulence coded as a cause or contributing factor.

Figure 13. Part 121 Aircraft Involved in Turbulence Accidents by Year



Between 2002 and 2013, 91 accidents involving part 121 aircraft occurred across five types of turbulence, resulting in 12,220 injury citations, of which 12,005 were no-injury, and none were fatal. General, convective, and clear air turbulence each made up nearly one-third of all turbulence citations. Figure 14 and Table 13 depict the number of injuries sustained by passengers and/or crewmembers aboard the aircraft by the type of turbulence.

Figure 14. Part 121 Turbulence Citations by Turbulence Type and Injuries Aboard

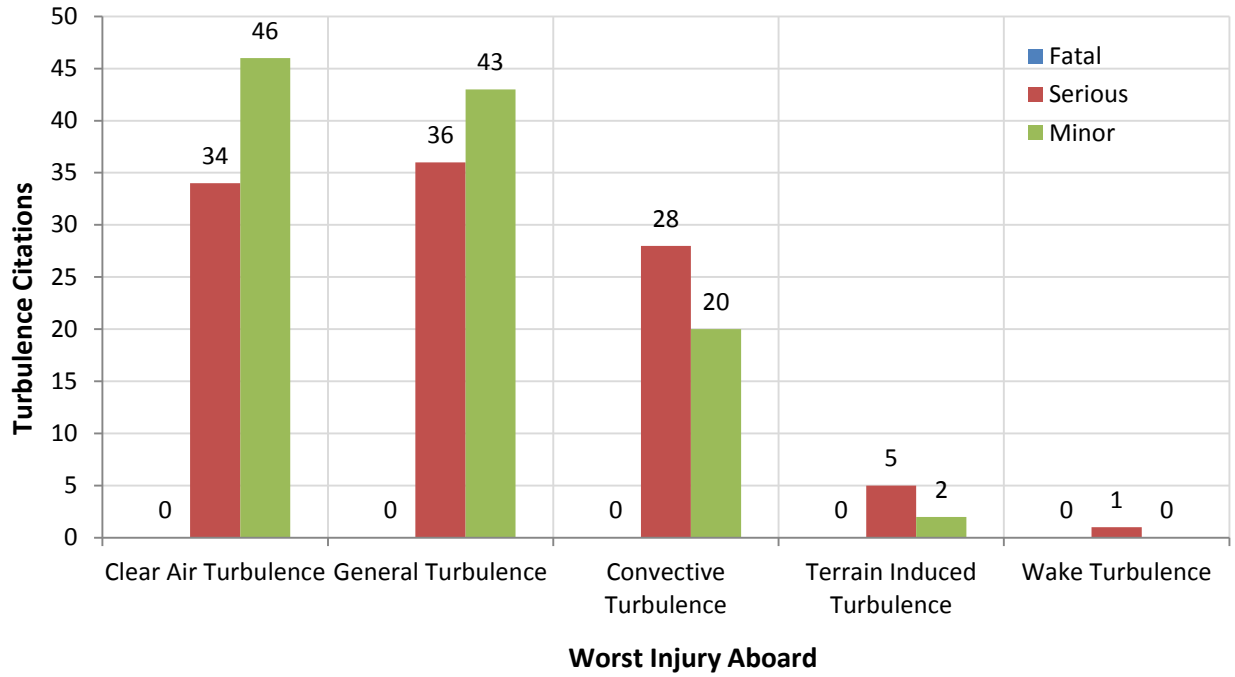


Table 13. Part 121 Turbulence Citations by Turbulence Type and Injuries Aboard

Turbulence Type	Fatal	Serious	Minor	None	Total
Clear Air Turbulence	0	34	46	3,891	3,971
General Turbulence	0	36	43	3,821	3,900
Convective Turbulence	0	28	20	3,829	3,877
Terrain-Induced Turbulence	0	5	2	418	425
Wake Turbulence	0	1	0	46	47
Total	0	104	111	12,005	12,220

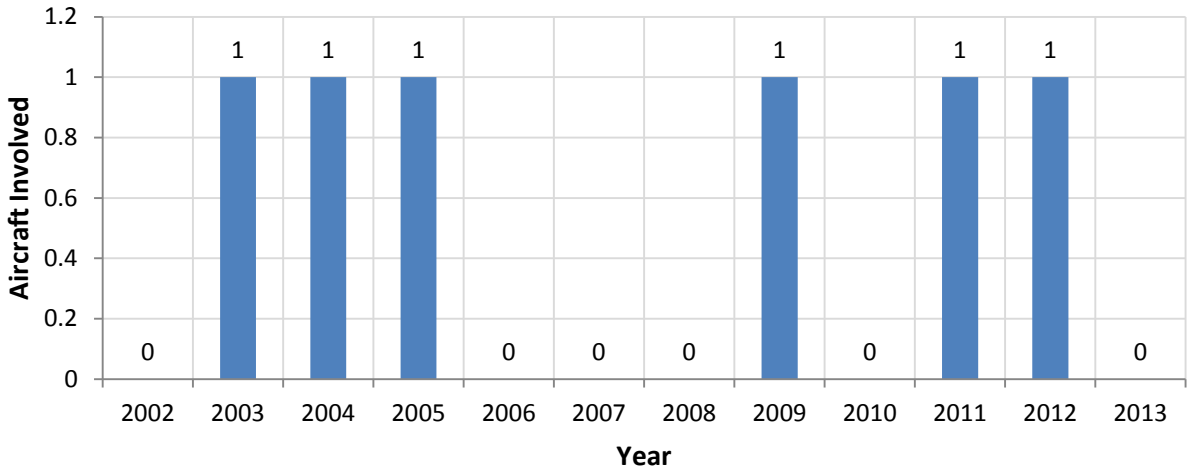
14 CFR Part 135 – Air Taxi and Commuter Review

Part 135 refers to either scheduled (commuter operations) or nonscheduled (air taxi operations) flights. Scheduled Part 135 operations apply to smaller aircraft carrying nine or fewer passengers on regularly scheduled routes. Nonscheduled Part 135 operations apply to smaller aircraft carrying nine or fewer passengers with schedules that are arranged between the passengers and the operator. Nonscheduled operations also include cargo airplanes with payload capacities of 7,500 pounds or less.

From 2002 to 2013, NTSB final reports identified turbulence as a cause or contributing factor in accidents involving 222 aircraft, including six aircraft operating under Part 135.

Although wake turbulence is included in the types of turbulence accounted for in this section, there were no wake turbulence accident reports for Part 135 aircraft during this period. This section focuses on the six Part 135 aircraft involved in turbulence accidents.

Figure 15. Part 135 Aircraft Involved in Turbulence Accidents by Year



Between 2002 and 2013, six accidents involving part 135 aircraft occurred across four types of turbulence, resulting in 17 injury citations, of which three were no-injury. The injury citations are shown below for each turbulence type. Figure 16 depicts the number of injuries sustained by passengers and/or crewmembers aboard the aircraft by the type of turbulence.

Figure 16. Part 135 Turbulence Citations by Turbulence Type and Injuries Aboard

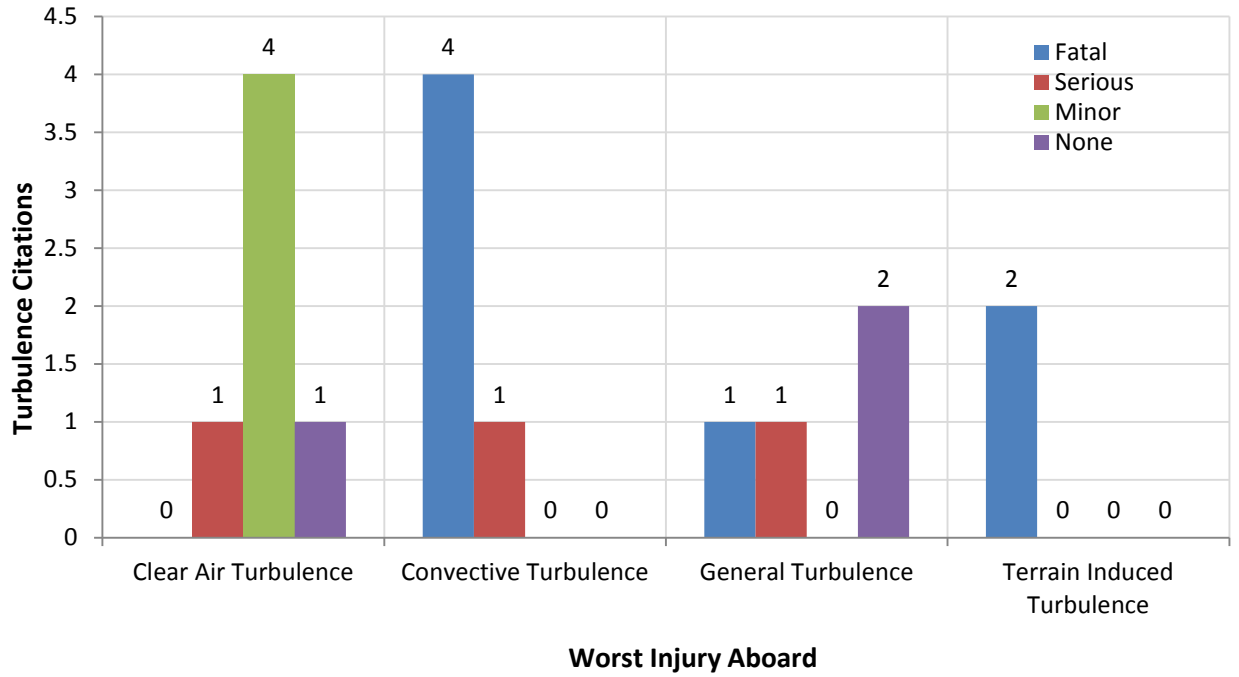


Table 14. Part 135 Turbulence Citations by Turbulence Type and Injuries Aboard

Turbulence Type	Fatal	Serious	Minor	None	Total
Clear Air Turbulence	0	1	4	1	6
Convective Turbulence	4	1	0	0	5
General Turbulence	1	1	0	2	4
Terrain-Induced Turbulence	2	0	0	0	2
Total	**7**	**3**	**4**	**3**	**17**

One-third of turbulence aircraft accidents involving Part 135 aircraft occurred in Alaska. States in which no Part 135 aircraft were involved in turbulence events were omitted from Table 15.

Table 15. Part 135 Aircraft Involved in Turbulence Accidents Aircraft by State

State	Accidents
Alaska	2
Arizona	1
California	1
South Dakota	1
Texas	1
Total	**6**

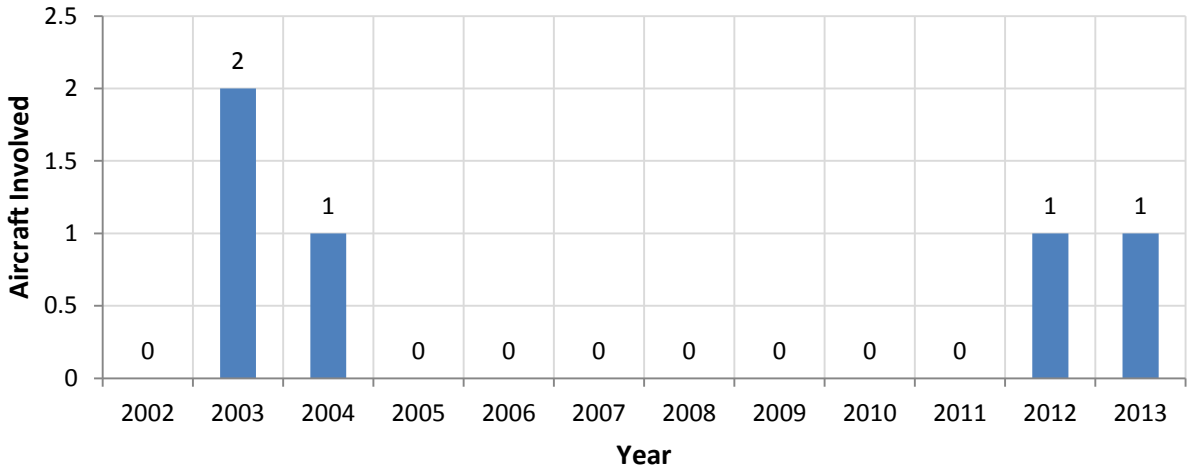
14 CFR Part 137 – Agricultural Operations Review

Part 137 refers to agricultural aircraft operations. Agricultural aircraft operation is defined as the operation of an aircraft for the purpose of (1) dispensing any economic poison; (2) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control; or (3) engaging in dispensing activities directly affecting agricultural, horticultural, or forest preservation, but not including the dispensing of live insects.

From 2002 to 2013, NTSB final reports identified turbulence as a cause or contributing factor in accidents involving 222 aircraft, including five aircraft operating under Part 137.

Although wake turbulence is included in the types of turbulence accounted for in this section, there were no wake turbulence accident reports for Part 137 aircraft during this period. This section focuses on the five Part 137 aircraft involved in turbulence accidents.

Figure 17. Part 137 Aircraft Involved in Turbulence Accidents by Year



Between 2002 and 2013, five accidents involving aircraft operating under Part 137 occurred across three types of turbulence, resulting in five injury citations, of which two were no-injury. The injury citations are shown below for each turbulence type. Figure 18 and Table 16 depict the number of injuries sustained by passengers and/or crewmembers aboard the aircraft by the type of turbulence.

Figure 18. Part 137 Turbulence Citations by Turbulence Type and Injuries Aboard

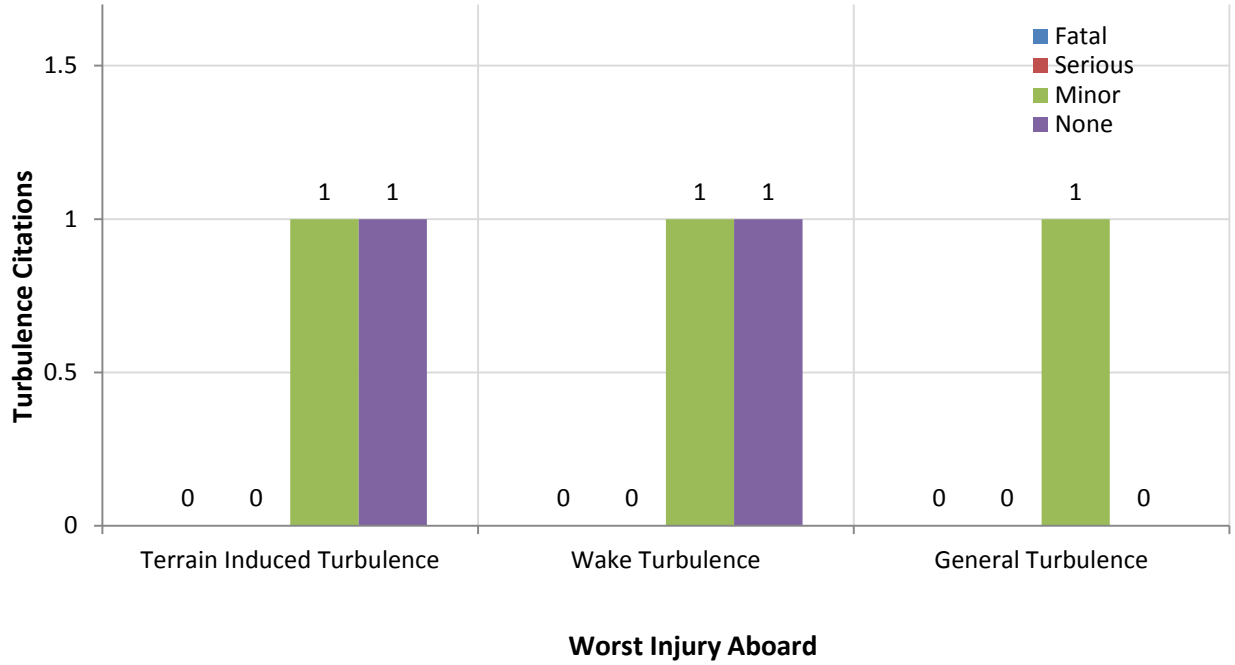


Table 16. Part 137 Turbulence Citations by Turbulence Type and Injuries Aboard

Turbulence Type	Fatal	Serious	Minor	None	Total
Terrain-Induced Turbulence	0	0	1	1	2
Wake Turbulence	0	0	1	1	2
General Turbulence	0	0	1	0	1
Total	0	0	3	2	5

THIS PAGE INTENTIONALLY LEFT BLANK

Appendix A. Glossary

Aircraft Accident: The NTSB defines an aircraft accident as an 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 all such persons have disembarked, and in which any person suffers death or serious injury, or in which the aircraft receives substantial damage.

Fatal Injury: The NTSB defines a fatal injury as any injury which results in death within 30 days of the accident.

14 CFR Part 91 (General Aviation): Part 91 prescribes rules governing the operation of aircraft (other than moored balloons, manned rockets, and unmanned free balloons, which are governed by Part 101, and ultralight vehicles operated in accordance with Part 103) within the United States, including the waters within three nautical miles of the U.S. coast. Flights operating for recreation and training are generally carried out under Part 91. Although general aviation usually involves small aircraft, the definition depends on the nature of the operation rather than the size of the aircraft.

14 CFR Part 121 (Air Carrier): Part 121 refers to scheduled domestic air carriers and cargo carriers that fly large transport category aircraft.

14 CFR Part 135 (Air Taxi and Commuter): Part 135 refers to either scheduled (commuter operations) or nonscheduled (air taxi operations) flights. Scheduled Part 135 operations apply to smaller aircraft carrying nine or fewer passengers on regularly scheduled routes. Nonscheduled Part 135 operations apply to smaller aircraft carrying nine or fewer passengers with schedules that are arranged between the passengers and the operator. Nonscheduled operations also include cargo planes with payload capacities of 7,500 pounds or less.

14 CFR Part 137 (Agricultural): Part 137 refers to agricultural aircraft operations. Agricultural aircraft operation is defined as the operation of an aircraft for the purpose of (1) dispensing any economic poison; (2) dispensing any other substance intended for plant nourishment, soil treatment, propagation of plant life, or pest control; or (3) engaging in dispensing activities directly affecting agricultural, horticultural, or forest preservation, but not including the dispensing of live insects.

Incident: The NTSB defines an incident as an occurrence other than an accident, associated with the operation of an aircraft, which affects or could affect the safety of operations.

Serious Injury: The NTSB defines a serious injury as any injury which (1) requires hospitalization for more than 48 hours, commencing within 7 days from the date the injury was received; (2) results in a fracture of any bone (except simple fractures of fingers, toes, or nose); (3) causes severe hemorrhages, 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.

Substantial Damage: The NTSB defines substantial damage as damage or failure that adversely affects the structural strength, performance, or flight characteristics of the aircraft, and that would normally require major repair or replacement of the affected component. Engine failure or damage limited to an engine if only one engine fails or is damaged, bent fairings or cowling, dented skin, small punctured holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, flaps, engine accessories, brakes, or wingtips are not considered "substantial damage" for the purpose of this definition.

Appendix B. Review of Pre- and Post-2008 Occurrence Coding in NTSB Aviation Accident Database

The changes the NTSB made to its aviation accident database in 2008 severed the link between occurrences and findings. These changes also created two new tables substituting for two older ones (which are retained for historical purposes). These new tables introduced new finding and occurrence codes that are used in the FINDING_CODE field of the NTSB2_FINDINGS_DATA table, and the OCCURRENCE_CODE field of the NTSB2_EVENTS_SEQUENCE_DATA table.

To explain the changes, this appendix takes advantage of the fact that the NTSB recorded the 2008 events using both the new and old methods. There were three accident events (20080220X00218, 20080624X00904, and 20081003X16303) in which turbulence was a cause or contributing factor. This means the following fields were queried:

Table Field	Value		Table Field	Value
NTSB2_EVENT_DATA EVENT_LCL_DATE	2008	AND	NTSB2_EVENT_DATA EVENT_ACDNT_INCDNT_CODE	'ACC'

AND

Table Field	Value		Table Field	Value
NTSB2_FINDINGS_DATA CAUSE_FACTOR_FLG	'C' or 'F'	AND	NTSB2_FINDINGS_DATA substr(FINDING_CODE, 1, 6)	030320
OR			OR	
NTSB2_SEQ_OF_EVENTS_DATA CAUSE_FACTOR_CODE			NTSB2_SEQ_OF_EVENTS_DATA SUBJECT_MODIFIER_CODE is in	2224, 2225, 2256
			OR	
			NTSB2_EVENTS_SEQUENCE_DATA EVENTSOE_NBR is in	360, 361, 362

Understanding Occurrence Codes Before 2008

When looking at pre-2008 coding, the ratio of occurrences (OCC_DESC) to subject is 2/5, 3/5, and 1/1. In the first two events, the NTSB found more than one subject for each occurrence. For example, the "Loss of Control – on Ground/Water" occurrence warranted one contributing factor ("Weather Condition/Turbulence, Terrain Induced") and two causes ("Airspeed/Excessive" and "Aircraft Control/Not Maintained"). The second occurrence ("In Flight Collision with Terrain/Water") warrants both a contributing factor and a subject that is neither a cause nor a contributing factor. Although this blank subject occurred, it was not deemed to affect the accident.

EVENT_ID	C/F	SUBJECT	SUBJECT_MODIFIER	OCC' NBR	OCC_DESC
20080220X00218	F	WEATHER CONDITION	TURBULENCE, TERRAIN INDUCED	1	LOSS OF CONTROL - ON GROUND/WATER
20080220X00218	C	AIRSPEED	EXCESSIVE	1	LOSS OF CONTROL - ON GROUND/WATER
20080220X00218	C	AIRCRAFT CONTROL	NOT MAINTAINED	1	LOSS OF CONTROL - ON GROUND/WATER
20080220X00218		ABORTED LANDING	ATTEMPTED	2	IN FLIGHT COLLISION WITH TERRAIN/WATER
20080220X00218	F	TERRAIN CONDITION	SNOWBANK	2	IN FLIGHT COLLISION WITH TERRAIN/WATER
20080624X00904	F	WEATHER CONDITION	TURBULENCE, TERRAIN INDUCED	1	IN FLIGHT ENCOUNTER WITH WEATHER
20080624X00904	C	AIRCRAFT CONTROL	NOT MAINTAINED	2	LOSS OF CONTROL - IN FLIGHT
20080624X00904	C	STALL	INADVERTENT	2	LOSS OF CONTROL - IN FLIGHT
20080624X00904		REMEDIAL ACTION	INITIATED	2	LOSS OF CONTROL - IN FLIGHT
20080624X00904	F	SUPERVISION	INADEQUATE	3	HARD LANDING
20081003X16303	C	WEATHER CONDITION	TURBULENCE, CLEAR AIR	1	IN FLIGHT ENCOUNTER WITH WEATHER

The occurrences describe the factual events that occurred surrounding the accident event, and thus do not attribute reasons for why the accident happened. That task is left for the SUBJECT and SUBJECT_MODIFIER fields. Instead, the OCC_DESC field is a list of aviation occurrences similar to, but not the same as, the "Aviation Occurrence Categories" published by the CAST/ICAO Common Taxonomy Team (CICTT). The two lists are shown below for comparison.

The SUBJECT and SUBJECT_MODIFIER fields above are more specific descriptions of the occurrence, or a reason the occurrence happened. For example, Stall/Inadvertent is a specific type of Loss Of Control – In Flight, while Supervision/Inadequate explains why the Hard Landing occurred. Because of this increased specificity over occurrences, some of the SUBJECT/SUBJECT_MODIFIERs also look like CICTT "Aviation Occurrence Categories," particularly related to turbulence. The CICTT occurrence "Turbulence Encounter (TURB)" is similar to "Weather Condition/Turbulence, Terrain Induced" in the table above.

The CAST/ICAO Common Taxonomy Team Aviation Occurrence Categories October 2013, V4.6	NTSB OCC_DESC's Pre-2008
ABNORMAL RUNWAY CONTACT (ARC)	ABRUPT MANEUVER
ABRUPT MANEUVER (AMAN)	AIRFRAME/COMPONENT/SYSTEM FAILURE/MALFUNCTION
AERODROME (ADRM)	ALTITUDE DEVIATION, UNCONTROLLED
AIRPROX/TCAS ALERT/LOSS OF SEPARATION/NEAR MIDAIR COLLISIONS/MIDAIR COLLISIONS (MAC)	CARGO SHIFT
ATM/CNS (ATM)	COLLISION BETWEEN AIRCRAFT (OTHER THAN MIDAIR)
BIRD (BIRD)	COMPLETE GEAR COLLAPSED
CABIN SAFETY EVENTS (CABIN)	DECOMPRESSION
COLLISION WITH OBSTACLE(S) DURING TAKEOFF AND LANDING (CTOL)	DITCHING
CONTROLLED FLIGHT INTO OR TOWARD TERRAIN (CFIT)	DRAGGED WING, ROTOR, POD, FLOAT OR TAIL/SKID
EVACUATION (EVAC)	ENGINE TEARAWAY
EXTERNAL LOAD RELATED OCCURRENCES (EXTL)	EXPLOSION
FIRE/SMOKE (NON-IMPACT) (F–NI)	FIRE
FIRE/SMOKE (POST-IMPACT) (F–POST)	FIRE/EXPLOSION
FUEL RELATED (FUEL)	FORCED LANDING
GLIDER TOWING RELATED EVENTS (GTOW)	GEAR COLLAPSED
GROUND COLLISION (GCOL)	GEAR NOT EXTENDED
GROUND HANDLING (RAMP)	GEAR NOT RETRACTED
ICING (ICE)	GEAR RETRACTION ON GROUND
LOSS OF CONTROL–GROUND (LOC–G)	HARD LANDING
LOSS OF CONTROL–INFLIGHT (LOC–I)	HAZARDOUS MATERIALS LEAK/SPILL (FUMES/SMOKE)
LOSS OF LIFTING CONDITIONS EN ROUTE (LOLI)	IN FLIGHT COLLISION WITH OBJECT
LOW ALTITUDE OPERATIONS (LALT)	IN FLIGHT COLLISION WITH TERRAIN/WATER
MEDICAL (MED)	IN FLIGHT ENCOUNTER WITH WEATHER
NAVIGATION ERRORS (NAV)	LOSS OF CONTROL - IN FLIGHT
OTHER (OTHR)	LOSS OF CONTROL - ON GROUND/WATER
RUNWAY EXCURSION (RE)	LOSS OF ENGINE POWER
RUNWAY INCURSION (RI)	LOSS OF ENGINE POWER (PARTIAL) - MECH FAILURE/MALF
SECURITY RELATED (SEC)	LOSS OF ENGINE POWER (PARTIAL) - NON-MECHANICAL
SYSTEM/COMPONENT FAILURE OR MALFUNCTION (NON-POWERPLANT) (SCF–NP)	LOSS OF ENGINE POWER (TOTAL) - MECH FAILURE/MALF
SYSTEM/COMPONENT FAILURE OR MALFUNCTION (POWERPLANT) (SCF–PP)	LOSS OF ENGINE POWER (TOTAL) - NON-MECHANICAL
TURBULENCE ENCOUNTER (TURB)	MAIN GEAR COLLAPSED
UNDERSHOOT/OVERSHOOT (USOS)	MIDAIR COLLISION
UNINTENDED FLIGHT IN IMC (UIMC)	MISCELLANEOUS/OTHER
UNKNOWN OR UNDETERMINED (UNK)	MISSING AIRCRAFT
WILDLIFE (WILD)	NEAR COLLISION BETWEEN AIRCRAFT
WIND SHEAR OR THUNDERSTORM (WSTRW)	NOSE DOWN
	NOSE GEAR COLLAPSED
	NOSE OVER
	NOT REPORTED
	ON GROUND/WATER COLLISION WITH OBJECT
	ON GROUND/WATER ENCOUNTER WITH TERRAIN/WATER
	ON GROUND/WATER ENCOUNTER WITH WEATHER
	OTHER GEAR COLLAPSED
	OVERRUN
	PROPELLER BLAST OR JET EXHAUST/SUCTION
	PROPELLER FAILURE/MALFUNCTION
	PROPELLER/ROTOR CONTACT TO PERSON
	ROLL OVER
	ROTOR FAILURE/MALFUNCTION
	TAIL GEAR COLLAPSED
	UNDERSHOOT
	UNDETERMINED
	VORTEX TURBULENCE ENCOUNTERED
	WHEELS DOWN LANDING IN WATER
	WHEELS UP LANDING

Understanding Occurrence Codes After 2008

In post-2008 coding, occurrences (the OCCURRENCE_DESC_TEXT field) cannot be linked to the FINDING_DESC_TEXT field because the NTSB2_FINDINGS_DATA table has no field for the NTSB2_EVENTS_SEQUENCE_DATA.OCCURRENCE_NBR or NTSB2_EVENTS_SEQUENCE_DATA.OCCURRENCE_DESC_TEXT. Additionally, the list of occurrences is not the same as the one used before 2008. The occurrences are made up of a prefix describing the phase of flight, followed by the occurrence itself. There are 48 prefixes and 95 occurrences to choose from, and these manifest in the dataset in almost 25,000 combinations.

EVENT_ID	C/F	F #	FINDING_DESC_TEXT
20080220X00218	F	1	Environmental issues-Conditions / weather / phenomena-Turbulence-Terrain induced turbulence-Not specified - F
20080220X00218	C	2	Aircraft-Aircraft oper / perf / capability-Performance / control parameters-Airspeed-Incorrect use / operation - C
20080220X00218	F	3	Environmental issues-Physical environment-Terrain-Snowy / icy-Not specified - F
20080220X00218	C	4	Personnel issues-Task performance-Use of equip / info-Aircraft control-Pilot - C
20080220X00218		5	Aircraft-Aircraft systems-Landing gear system-Main landing gear-Damaged / degraded
20080624X00904	C	1	Personnel issues-Task performance-Use of equip / info-Aircraft control-Pilot - C
20080624X00904	C	2	Aircraft-Aircraft oper / perf / capability-Performance / control parameters-Airspeed-Not attained / maintained - C
20080624X00904	F	3	Personnel issues-Psychological-Attention / monitoring-Monitoring other person-Instructor / check pilot - F
20080624X00904	F	4	Environmental issues-Conditions / weather / phenomena-Turbulence-Terrain induced turbulence-Effect on operation - F
20081003X16303	C	1	Environmental issues-Conditions / weather / phenomena-Turbulence-Clear air turbulence-Effect on personnel - C
20081003X16303	C	2	Environmental issues-Conditions / weather / phenomena-Turbulence-Clear air turbulence-Ability to respond / compensate - C

O #	Code	OCCURRENCE_DESC_TEXT
1	500360	Approach - Turbulence encounter
2	550230	Landing - Loss of control on ground
3	509470	Approach-VFR go-around - Collision with terr / obj (non-CFIT)
4	509338	Approach-VFR go-around - Part(s) separation from AC
5	550090	Landing - Abnormal runway contact
6	550300	Landing - Runway excursion
1	508360	Approach-VFR pattern final - Turbulence encounter
2	551240	Landing-flare / touchdown - Loss of control in flight
3	551092	Landing-flare / touchdown - Hard landing
1	402362	Enroute-cruise - Clear air turbulence encounter

Roughly half of the pre- and post-2008 occurrence codes for the three turbulence-related accidents in 2008 map to one another.

Pre-2008 OCC_DESC		Post-2008 OCCURRENCE_DESC_TEXT suffix
		Turbulence encounter
LOSS OF CONTROL - ON GROUND/WATER	=	Loss of control on ground
IN FLIGHT COLLISION WITH TERRAIN/WATER	=	Collision with terr/obj (non-CFIT)
		Part(s) separation from AC
		Abnormal runway contact
		Runway excursion
LOSS OF CONTROL - IN FLIGHT	=	Loss of control in flight
HARD LANDING	=	Hard landing
		Clear air turbulence encounter
IN FLIGHT ENCOUNTER WITH WEATHER		

As with the pre-2008 occurrences, the post-2008 occurrences describe the factual events that occurred surrounding the accident event and thus do not attribute reasons for why the accident happened. That task is left for the FINDING_DESC_TEXT field. Instead, the OCCURRENCE_DESC_TEXT suffix field is a list of aviation occurrences similar to, but not the same as, the CICTT "Aviation Occurrence Categories." The two lists are shown below for comparison.

The FINDING_DESC_TEXT fields above are formed by combining selections, left to right, from the lists that coincide with the column headings of the table below. Each column gives information best illustrated by the examples below, and becomes more specific moving from left to right.

CATEGORY	SUBCATEGORY	SECTION	SUBSECTION	MODIFIER	CF
AIRCRAFT	AIRCRAFT SYSTEMS	LANDING GEAR SYSTEM	MAIN LANDING GEAR	DAMAGED / DEGRADED	
AIRCRAFT	AIRCRAFT OPER / PERF / CAPABILITY	PERFORMANCE / CONTROL PARAMETERS	AIRSPEED	INCORRECT USE / OPERATION	C
PERSONNEL ISSUES	TASK PERFORMANCE	USE OF EQUIP / INFO	AIRCRAFT CONTROL	PILOT	C
ENVIRONMENTAL ISSUES	PHYSICAL ENVIRONMENT	TERRAIN	SNOWY / ICY	NOT SPECIFIED	F
ENVIRONMENTAL ISSUES	CONDITIONS / WEATHER / PHENOMENA	TURBULENCE	TERRAIN INDUCED TURBULENCE	NOT SPECIFIED	F

Notice the CICTT occurrence, "Turbulence Encounter (TURB)" below, is similar to "Weather Condition"/"Turbulence, Terrain Induced" in the table above.

CICTT Aviation Occurrence Categories October 2013, V4.6	NTSB2_EVENTS_SEQUENCE_DATA OCCURRENCE_DESC_TEXT Suffix Post-2008
ABNORMAL RUNWAY CONTACT (ARC)	Abnormal runway contact
ABRUPT MANEUVER (AMAN)	Abrupt maneuver
AERODROME (ADRM)	AC / prop / rotor contact w person
AIRPROX / TCAS ALERT / LOSS OF SEPARATION / NEAR MIDAIR COLLISIONS / MIDAIR COLLISIONS (MAC)	Aerodynamic stall / spin
ATM / CNS (ATM)	Air traffic event
BIRD (BIRD)	Aircraft inspection event
CABIN SAFETY EVENTS (CABIN)	Aircraft loading event
COLLISION WITH OBSTACLE(S) DURING TAKEOFF AND LANDING (CTOL)	Aircraft maintenance event
CONTROLLED FLIGHT INTO OR TOWARD TERRAIN (CFIT)	Aircraft servicing event
EVACUATION (EVAC)	Aircraft structural failure
EXTERNAL LOAD RELATED OCCURRENCES (EXTL)	**Aircraft wake turb encounter**
FIRE / SMOKE (NON-IMPACT) (F–NI)	Airport occurrence
FIRE / SMOKE (POST-IMPACT) (F–POST)	Altitude deviation
FUEL RELATED (FUEL)	Attempted remediation / recovery
GLIDER TOWING RELATED EVENTS (GTOW)	Birdstrike
GROUND COLLISION (GCOL)	Cabin safety event
GROUND HANDLING (RAMP)	**Clear air turbulence encounter**
ICING (ICE)	Collision avoidance alert
LOSS OF CONTROL–GROUND (LOC–G)	Collision during takeoff / land
LOSS OF CONTROL–INFLIGHT (LOC–I)	Collision with terr / obj (non-CFIT)
LOSS OF LIFTING CONDITIONS EN ROUTE (LOLI)	Collision with terr / obj (non-CFIT)
LOW ALTITUDE OPERATIONS (LALT)	Comm system malf / failure
MEDICAL (MED)	Controlled flight into terr / obj (CFIT)
NAVIGATION ERRORS (NAV)	Course deviation
OTHER (OTHR)	Ditching

CICTT Aviation Occurrence Categories October 2013, V4.6	NTSB2_EVENTS_SEQUENCE_DATA OCCURRENCE_DESC_TEXT Suffix Post-2008
RUNWAY EXCURSION (RE)	Dragged wing / rotor / float / other
RUNWAY INCURSION (RI)	Dynamic rollover
SECURITY RELATED (SEC)	Electrical system malf / failure
SYSTEM / COMPONENT FAILURE OR MALFUNCTION (NON-POWERPLANT) (SCF–NP)	Emergency descent initiated
SYSTEM / COMPONENT FAILURE OR MALFUNCTION (POWERPLANT) (SCF–PP)	Engine shutdown
TURBULENCE ENCOUNTER (TURB)	Evacuation
UNDERSHOOT / OVERSHOOT (USOS)	Explosion (non-impact)
UNINTENDED FLIGHT IN IMC (UIMC)	Explosion (post-impact)
UNKNOWN OR UNDETERMINED (UNK)	External load event (Rotorcraft)
WILDLIFE (WILD)	Fire / smoke (non-impact)
WIND SHEAR OR THUNDERSTORM (WSTRW)	Fire / smoke (post-impact)
	Flight control sys malf / fail
	Flight instrument malf / fail
	Fuel contamination
	Fuel exhaustion
	Fuel related
	Fuel starvation
	Glider tow event
	Ground collision
	Ground handling event
	Ground resonance
	Hard landing
	Hazardous material leak / spill
	Inflight upset
	Landing area overshoot
	Landing area undershoot
	Landing gear collapse
	Landing gear not configured
	Loss of control in flight
	Loss of control on ground
	Loss of engine power (partial)
	Loss of engine power (total)
	Loss of lift
	Loss of tail rotor effectiveness
	Loss of visual reference
	Low altitude operation / event
	Mast bumping
	Midair collision
	Miscellaneous / other
	Missing aircraft
	Nav system malfunction / failure
	Near midair / TCAS alert / loss of separation
	Nose over / nose down
	Off-field or emergency landing
	Other weather encounter
	Part(s) separation from AC
	Powerplant sys / comp malf / fail
	Preflight or dispatch event
	Pressure / environ sys malf / fail
	Prop / jet / rotor blast / suction
	Roll over
	Runway excursion
	Runway incursion animal
	Runway incursion veh / AC / person
	Security / criminal event
	Settling with power / vortex ring state
	Simulated / training event

CICTT Aviation Occurrence Categories October 2013, V4.6	NTSB2_EVENTS_SEQUENCE_DATA OCCURRENCE_DESC_TEXT Suffix Post-2008
	Stall warn / stick-shaker / pusher
	Structural icing
	Sys / Comp malf / fail (non-power)
	Tailstrike
	Terrain avoidance alert
	Turbulence encounter
	Uncontained engine failure
	Unknown or undetermined
	VFR encounter with IMC
	Wildlife encounter (non-bird)
	Windshear or thunderstorm
	Wrong fuel