Review of Aviation Accidents Involving Weather Turbulence in the United States

1992-2001

August 2004

NASDAC

National Aviation Safety Data Analysis Center
FAA Office of System Safety
www.nasdac.faa.gov

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Executive Summary

From 1992 to 2001, there were 4,326 weather accidents that occurred in the United States. Of these 4,326 accidents, 509 were cited as turbulence weather events. Nearly 23 percent of these turbulence-related accidents resulted in fatal injuries to the occupants of the aircraft. General aviation turbulence accidents have been reduced by almost 60 percent in 2001, compared with the data from 1992. The National Transportation Safety Board (NTSB) cited downdraft as the cause or factor most often in the general aviation accidents. Clear air turbulence was cited most often in the air carrier accidents.

Introduction

This study was written by the analyst staff at the National Aviation Safety Data Analysis Center (NASDAC), which is a part of the Federal Aviation Administration's (FAA's) Office of System Safety (ASY-100). It is presented as an information summary regarding weather turbulence events occurring in the United States between the years 1992 and 2001.

Data Source – National Transportation Safety Board (NTSB)

Data was extracted from the National Transportation Safety Board (NTSB) Aviation Accident/Incident Data System. The NTSB is the official U.S. repository of aviation accident data and causal factors. The NTSB, an independent Federal Agency not part of the Department of Transportation (DOT), maintains the data.

The NTSB database contains information relating to accidents and a small number of incidents, which are not included in this publication. 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 investigative process can take five or more years to finalize the report, with an average of two to three years.

The database includes preliminary, factual, and final reports. The preliminary status of a report is the first stage of the investigation process, and holds basic information regarding the event. The preliminary report is generally available from the NTSB within a few days of the happening, but it is subject to change. The factual status of a report will contain more information as it becomes available to the investigator. Lastly, the final status of the report replaces the factual and preliminary reports when the NTSB investigation is complete. Only the final report will include the probable cause(s) of the accident or incident. In determining the probable cause(s) of an accident, all facts, conditions, and circumstances are considered by the NTSB. Within each accident occurrence, any information that contributes to the explanation of that event is identified as a 'finding' and may be further designated as either a 'cause' or 'factor.' The term 'factor' is used to describe situations or circumstances that contributed to the accident cause. Just as accidents often include a series of occurrences, the reasons why these occurrences lead to an accident may be the combination of multiple causes and factors. For this reason, a single accident record may include multiple causes and factors. Each report has a minimum of one occurrence and one cause.

This study is based on a data set that has a currency date of 29-July-2004.

Data Criteria

The following conditions were used to extract the data from the National Transportation Safety Board (NTSB) Aviation Accident/Incident Data System:

1. Years from 1992 through 2001
2. Accidents only
3. Final report status
4. United States only (not including U.S. territories such as the Virgin Islands, Puerto Rico, Guam etc.)
5. Weather as a cause or factor (findings are not included). This field is titled 'Subject' in the database and is coded as 20000.
6. Turbulence weather as a cause or factor (findings are not included). This field is title 'Subject Modifier' in the database. Please see Figure 1 for the total list of Subject Modifiers used for turbulence weather events, as defined by the NTSB Coding Manual.

Figure 1. Turbulence Weather Condition Codes and Descriptions

NTSB Subject Modifier Code	Description
2205	Downdraft
2217	Mountain Wave
2224	Turbulence
2225	Turbulence, Clear Air
2226	Turbulence, In Clouds
2227	Turbulence, Thunderstorms
2236	Updraft
2253	Turbulence, Terrain Induced
2256	Turbulence, Convection Induced

There are separate reports issued for each aircraft involved in an aviation accident. This publication will specify the type of count the data presented is showing, whether it is an 'aircraft count' or 'event count.'

It is important to note that some of the turbulence events will not be captured in this study due to the search criteria. Many of the air carrier events in which a passenger or crew member experienced minor injuries (such as a broken finger) due to turbulence will not be included in this study. This circumstance does not meet the National Transportation Safety Board's definition of an accident and therefore will not be presented. The majority of these events are collected in the Federal Aviation Administration Accident/Incident Data System (AIDS), which can be viewed and searched on the NASDAC website – https://www.nasdac.faa.gov.

Report Preparation Facility - National Aviation Safety Data Analysis Center (NASDAC)

The Federal Aviation Administration (FAA) promotes the open exchange of safety information in order to continuously improve aviation safety. To further this basic objective, the FAA established the National Aviation Safety Data Analysis Center (NASDAC). The NASDAC system houses one of the most extensive collections of U.S. and international aviation safety data in the world. By providing a suite of advanced analysis tools and database search capabilities, NASDAC has quickly grown to be a leading provider of safety information to the aerospace industry. The NASDAC mission is to enhance system safety decision-making by providing high quality safety information, analysis services, and technology to the aerospace community. NASDAC supports the overall FAA mission: To provide a safe, secure, and efficient global aerospace system that contributes to national security and the promotion of U.S. aerospace safety. For more information regarding NASDAC, please contact:

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FAA Employee Secured Access: https://extranet.nasdac.faa.gov *(Federal Aviation Administration employees are invited to visit this site and request a login.)*

Weather and Turbulence

Accident Comparison – Ten-Year Review

From 1992 to 2001, there were a total of 20,332 accidents that occurred in the United States. During this same time period, the National Transportation Safety Board (NTSB) cited weather as a cause or factor in 4,326 accidents. Of these weather events, the NTSB cited weather turbulence as a cause or factor in 509 accidents, or eleven percent of the total weather accidents.

Figure 2. Comparison of Weather Accidents to Weather Turbulence Accidents

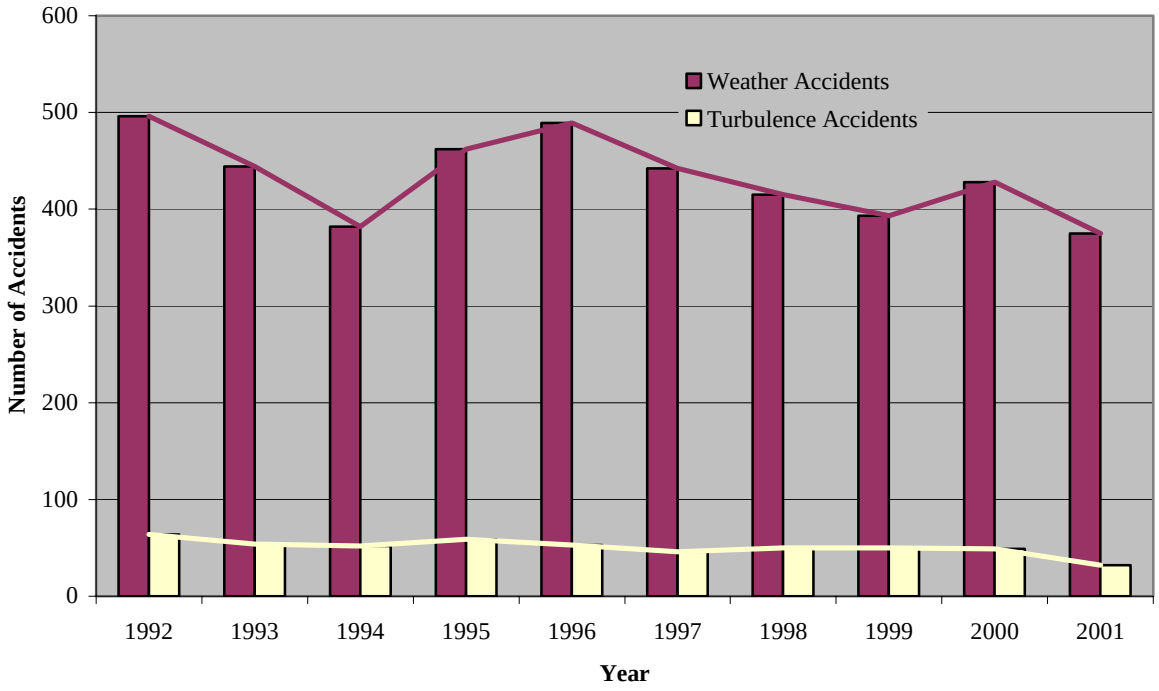


Figure 3. Percentage of Weather Turbulence Accident to Weather Accidents

Year	Weather Accidents	Turbulence Accidents	Percentage of Turbulence Accidents to Weather Accidents
1992	496	64	12.90%
1993	444	54	12.16%
1994	382	52	13.61%
1995	462	59	12.77%
1996	489	53	10.84%
1997	442	46	10.41%
1998	415	50	12.05%
1999	393	50	12.72%
2000	428	49	11.45%
2001	375	32	8.53%
Total	**4,326**	**509**	**11.77%**

Figure 4 is the breakout of type of weather citations in the 4,326 accidents. There are a total of 6,016 weather citations for the weather events, and 548 turbulence citations, which is over nine percent of the total weather causes.

Figure 4. Total Weather Accidents by Phenomenon

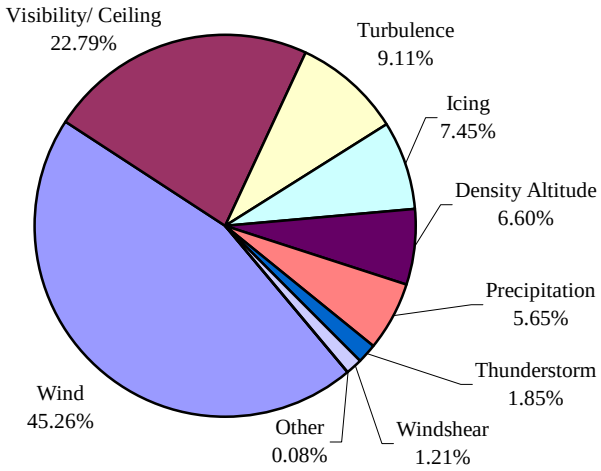


Figure 5. Total Weather Accidents by Phenomenon

Type of Weather	Number of Citations
Wind	2723
Visibility/ Ceiling	1371
Turbulence	***548***
Icing	448
Density Altitude	397
Precipitation	340
Thunderstorm	111
Windshear	73
Other	5
Total	**6,016**

Accident Comparison – Injury Review

From 1992 to 2001, in the United States, there were 1,067 weather-related fatal accidents which resulted in 2,237 fatalities on board the aircraft. During this same time range, there were 115 fatal accidents which resulted in 251 fatal injuries on board the aircraft where turbulent weather conditions were cited as the cause or factor. From 1992 to 2001, turbulence accounted for over 10 percent of the fatal weather accidents and over 11 percent of the fatalities due to weather conditions.

Figure 6. Fatal Weather Accidents Compared to Fatal Weather Turbulence Accidents

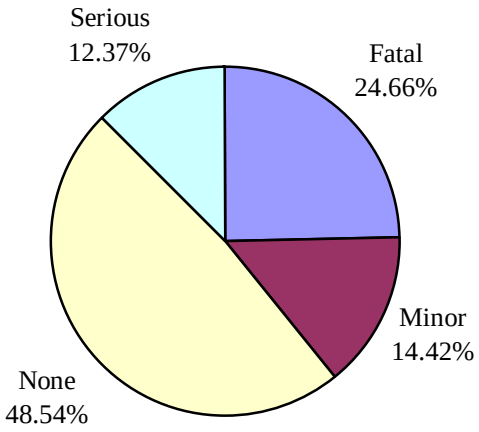
Year	Fatal Weather Accidents	Fatal Turbulence Accidents	Percentage Fatal Turbulence Accidents to Fatal Weather Accidents
1992	150	12	8.00%
1993	119	14	11.76%
1994	101	14	13.86%
1995	121	13	10.74%
1996	121	16	13.22%
1997	101	13	12.87%
1998	103	14	13.59%
1999	72	8	11.11%
2000	104	6	5.77%
2001	75	5	6.67%
Total	**1,067**	**115**	**10.78%**

Figure 7. Weather Fatalities Compared to Weather Turbulence Fatalities

Year	Weather Fatalities	Weather Turbulence Fatalities	Percentage of Weather Turbulence Fatalities to Weather Fatalities
1992	358	38	10.61%
1993	274	36	13.14%
1994	233	27	11.59%
1995	240	27	11.25%
1996	227	37	16.30%
1997	205	27	13.17%
1998	186	22	11.83%
1999	158	17	10.76%
2000	204	13	6.37%
2001	152	7	4.61%
Total	**2,237**	**251**	**11.22%**

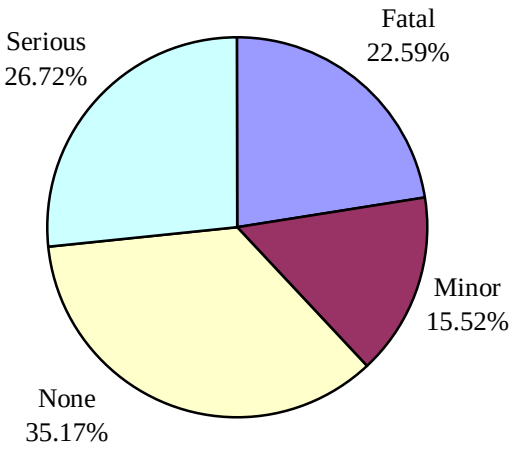
Figures 8and 9 depict the distribution of injury severity for accidents due to weather conditions and turbulent weather conditions, respectively from 1992 to 2001 in the United States. The data indicates that weather turbulence resulted in serious injuries more often (as a percentage) than the total weather accidents (26.72 percent versus 12.37 percent).

Figure 8. Weather Accidents – Injury Severity



Injury Severity	Number of Weather Accidents
Fatal	1067
Serious	535
Minor	624
None	2100
Total	**4,326**

Figure 9. Weather Turbulence Accidents – Injury Severity



Injury Severity	Turbulence Accidents
Fatal	115
Minor	79
None	179
Serious	136
Total	**509**

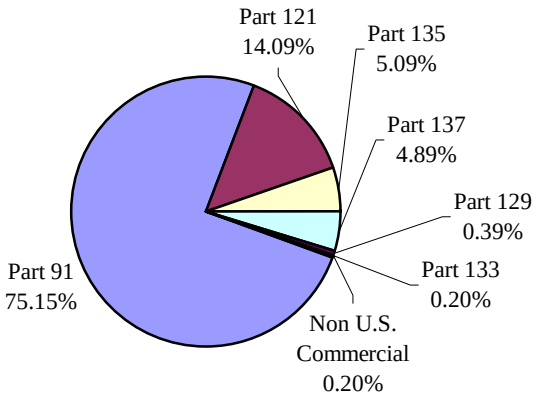
Weather Turbulence Accidents – Operating Flight Rules Review

From 1992 to 2001, accidents involving weather turbulence occurred during various operating rules of Title 14 Code of Federal Aviation Regulations. The FAA establishes the rules and regulations that coincide with each of the FAR Parts. These include:

- Part 91 – General aviation (recreation, training, etc.)
- Part 121 – Scheduled airlines and cargo carriers that fly large transport-category aircraft
- Part 129 – Foreign air carriers
- Part 133 – Rotorcraft external-load operations
- Part 135 – Scheduled or non-scheduled air taxi operations (nine or fewer passengers)
- Part 137 – Agricultural aircraft operations
- Non U.S. Commercial

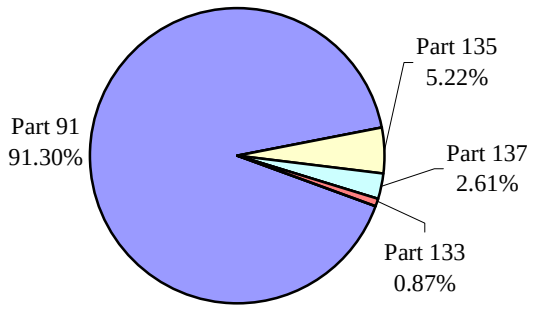
The majority of the weather turbulence accidents occurred during Part 91 operations, depicted in Figures 10 and 11.

Figure 10. Weather Turbulence Accidents by Operation (Aircraft Count)



FAR Part	Total Turbulence Accidents	Percentage of Turbulence Accidents
Part 91	384	75.15%
Part 121	72	14.09%
Part 135	26	5.09%
Part 137	25	4.89%
Part 129	2	0.39%
Part 133	1	0.20%
Non U.S. Commercial	1	0.20%
Grand Total	**511**	**100.00%**

Figure 11. Fatal Weather Turbulence Accidents by Operation (Aircraft Count)



FAR Part	Fatal Turbulence Accidents	Percentage of Fatal Turbulence Accidents
Part 91	105	91.30%
Part 121	0	0.00%
Part 135	6	5.22%
Part 137	3	2.61%
Part 129	0	0.00%
Part 133	1	0.87%
Non U.S. Commercial	0	0.00%
Grand Total	**115**	**100.00%**

Part 91 – General Aviation Review

FAR Part 91, or general aviation, 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.

From 1992 to 2001, weather turbulence was identified as a cause or factor in 509 accidents. General aviation accounted for 384 of these accidents, which will be discussed in this section.

The number of general aviation accidents due to weather turbulence has been decreasing since 1992. When comparing the number of events that occurred at year-end 1992 with those that occurred at year-end 2001, there has been a reduction of almost 60 percent.

Figure 12. General Aviation Weather Turbulence Accidents by Year

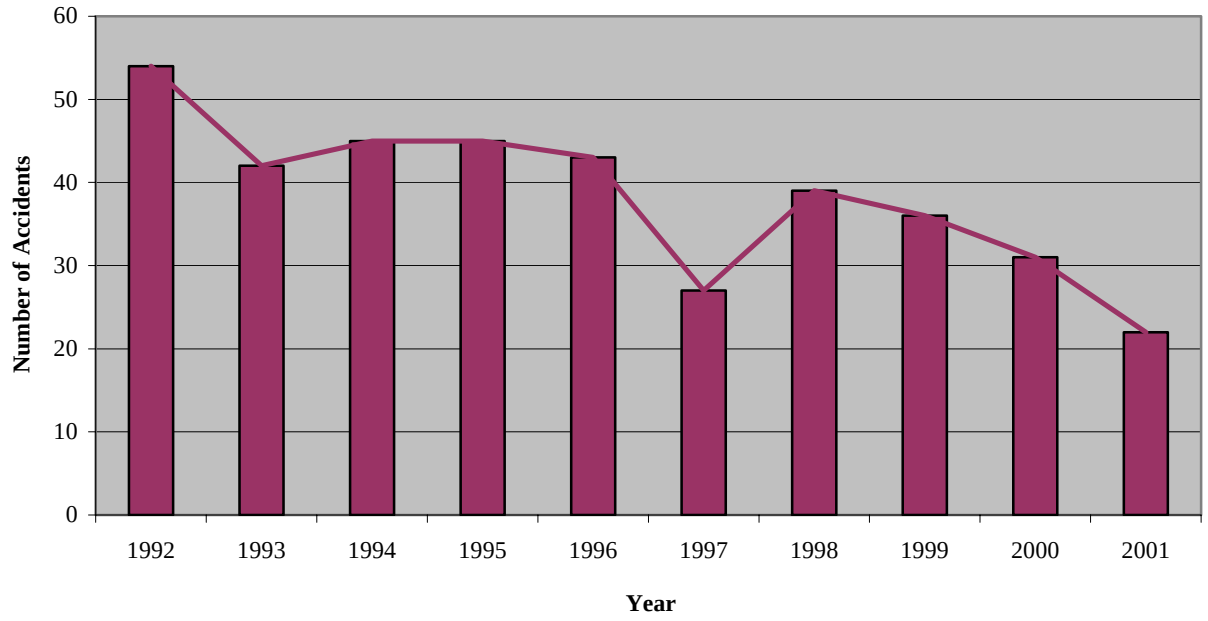
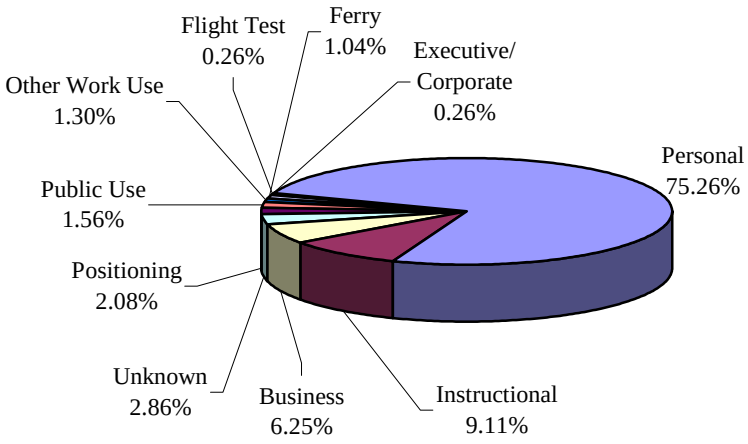


Figure 13. General Aviation Weather Turbulence Accidents – Year

Year	Number of Accidents	Percentage of Part 91 Weather Turbulence Accidents
1992	54	14.06%
1993	42	10.94%
1994	45	11.72%
1995	45	11.72%
1996	43	11.20%
1997	27	7.03%
1998	39	10.16%
1999	36	9.38%
2000	31	8.07%
2001	22	5.73%
Total	**384**	**100.00%**

General aviation operations can be classified further by the specific use of the aircraft for the individual flight. The majority of the weather turbulence events involving general aviation operations involve personal use flights, followed distantly by instruction.

Figure 14. General Aviation Weather Turbulence Accidents – Aircraft Use (Aircraft Count)



Aircraft Use	Number of Aircraft
Personal	289
Instructional	35
Business	24
Unknown	11
Positioning	8
Public Use	6
Other Work Use	5
Ferry	4
Executive/ Corporate	1
Flight Test	1
Total	**384**

There is a noticeable increase in weather turbulence events that occur in the summer months, peaking in July, between 1992 and 2001.

Figure 15. General Aviation Weather Turbulence Accidents by Month

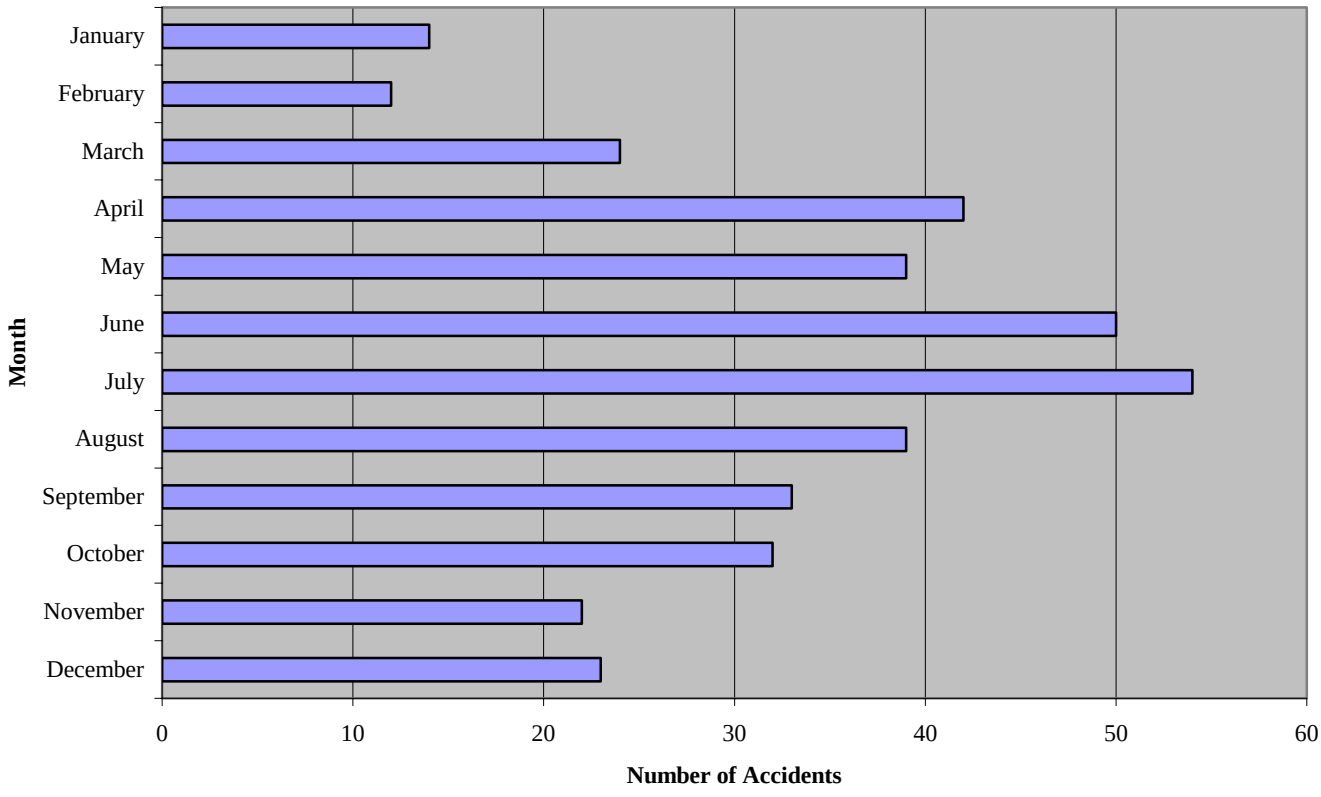


Figure 16. General Aviation Weather Turbulence Accidents – Month

Month	Number of Accidents	Percent of Part 91 Weather Turbulence Accidents
January	14	3.65%
February	12	3.13%
March	24	6.25%
April	***42***	***10.94%***
May	***39***	***10.16%***
June	***50***	***13.02%***
July	***54***	***14.06%***
August	***39***	***10.16%***
September	33	8.59%
October	32	8.33%
November	22	5.73%
December	23	5.99%
Total	**384**	**100.00%**

California and Alaska are the top two states for weather turbulence involving general aviation, followed by Colorado and New Mexico. Among the turbulence causes and factors, mountainous terrain was also a cause or factor 70 times. The locations of these events are highlighted in Figure 17. Notice that the top six states are included in this grouping.

Figure 17. General Aviation Weather Turbulence Accidents – State (Event Count)

State	Number of Events
****California***	***56***
****Alaska***	***47***
****Colorado***	***22***
****New Mexico***	***20***
****Wyoming***	***16***
****Washington***	***16***
Florida	16
****Idaho***	***14***
****Arizona***	***13***
Texas	11
****Utah***	***10***
****Oregon***	***10***
****Montana***	***10***
****Nevada***	***9***
Alabama	7
Wisconsin	7
Pennsylvania	7
Oklahoma	7
Missouri	7
Iowa	6
Massachusetts	6
****New York***	***6***
Virginia	5
Michigan	5
Georgia	5
North Carolina	5

State (Con't)	Number of Events
****Hawaii***	***4***
****Vermont***	***3***
Maryland	3
Louisiana	3
New Jersey	3
Indiana	3
Kansas	2
Arkansas	2
Ohio	2
Mississippi	2
Connecticut	2
Illinois	2
Tennessee	2
North Dakota	2
Nebraska	2
Minnesota	1
New Hampshire	1
Maine	1
Kentucky	1
Delaware	0
Rhode Island	0
South Carolina	0
South Dakota	0
West Virginia	0
Total	**384**

* These states include weather turbulence as well as mountainous terrain in the probable cause statement.

One example of a mountainous terrain event resulted in a substantially damaged aircraft with no sustained injures. A pilot encountered strong winds aloft when he entered a mountain pass at 10,500 feet MSL in Colorado. He experienced a severe downdraft that caused an 800-foot altitude loss, putting the airplane below the ridgeline. The pilot attempted to turn away from the ridge, but was unable to clear the terrain. He flared the airplane to reduce the forward airspeed before impacting deep snow.
The cause was determined to be the pilot's selection of too low an altitude in high mountainous terrain.
NTSB Report Number: FTW94LA105

When examining Part 91 operations, the most common result of weather turbulence events is substantially damaged aircraft and no injuries sustained by the passengers and/or crew.

Figure 18. General Aviation Weather Turbulence Accidents by Aircraft Damage and Injury Severity (Aircraft Count)

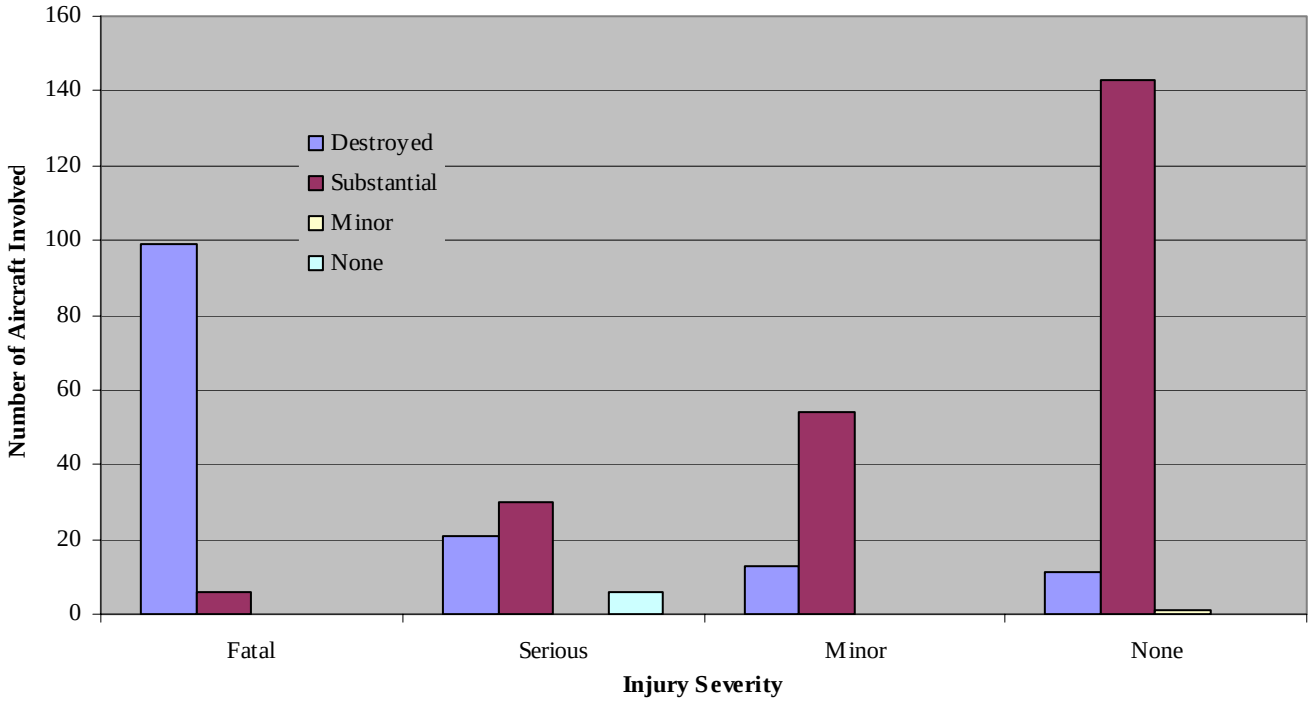
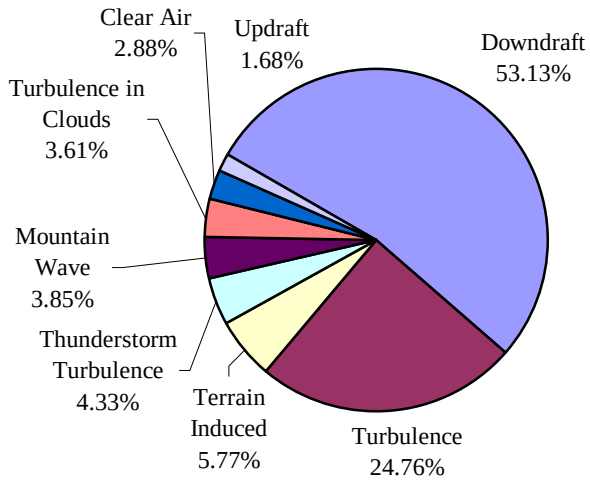


Figure 19. General Aviation Weather Turbulence Accidents – Aircraft Damage and Injury Severity (Aircraft Count)

	Fatal	Serious	Minor	None	Total
Destroyed	99	21	13	11	144
Substantial	6	30	54	143	233
Minor	0	0	0	1	1
None	0	6	0	0	6
Total	**105**	**57**	**67**	**155**	**384**

The following counts are based on the number of causes and factors identified by the NTSB accident investigator. It is possible that a single event has more than one weather turbulence cause or factor cited. For example, an individual aircraft may have encountered a downdraft and terrain induced turbulence in one event. For the 384 aircraft, there are 416 weather turbulence-related causes and/or factors cited. The specific type of turbulence involving general aviation operations from 1992 through 2001 varied. However, the NTSB cited downdraft as the cause or factor most often in these accidents.

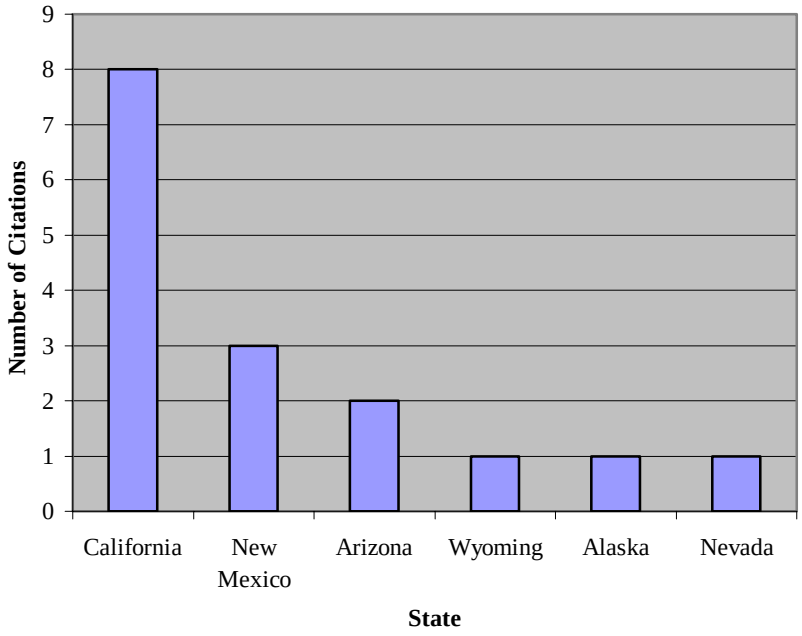
Figure 20. General Aviation Weather Turbulence Accidents – Type of Turbulence



Type of Turbulence	Total
Downdraft	221
Turbulence	103
Terrain Induced	24
Thunderstorm Turbulence	18
Mountain Wave	16
Turbulence in Clouds	15
Clear Air	12
Updraft	7
Total	**416**

All of the mountain wave events involving general aviation aircraft occurred in the same six states. Most of these states also appear at the top of the overall general aviation weather turbulence events (see Figure 16).

Figure 21. General Aviation Mountain Wave Accidents by State



State	Number of Citations
California	8
New Mexico	3
Arizona	2
Wyoming	1
Alaska	1
Nevada	1
Total	**16**

While examining the breakout percentages of the types of turbulence for general aviation events, it is interesting to note the distribution of injury severity. Although downdraft accounts for the majority of the turbulence events, almost fifty percent of these events result in no injuries, and a little over ten percent involved fatalities.

Figure 22. General Aviation Weather Turbulence Accidents by Types of Turbulence and Injury Severity

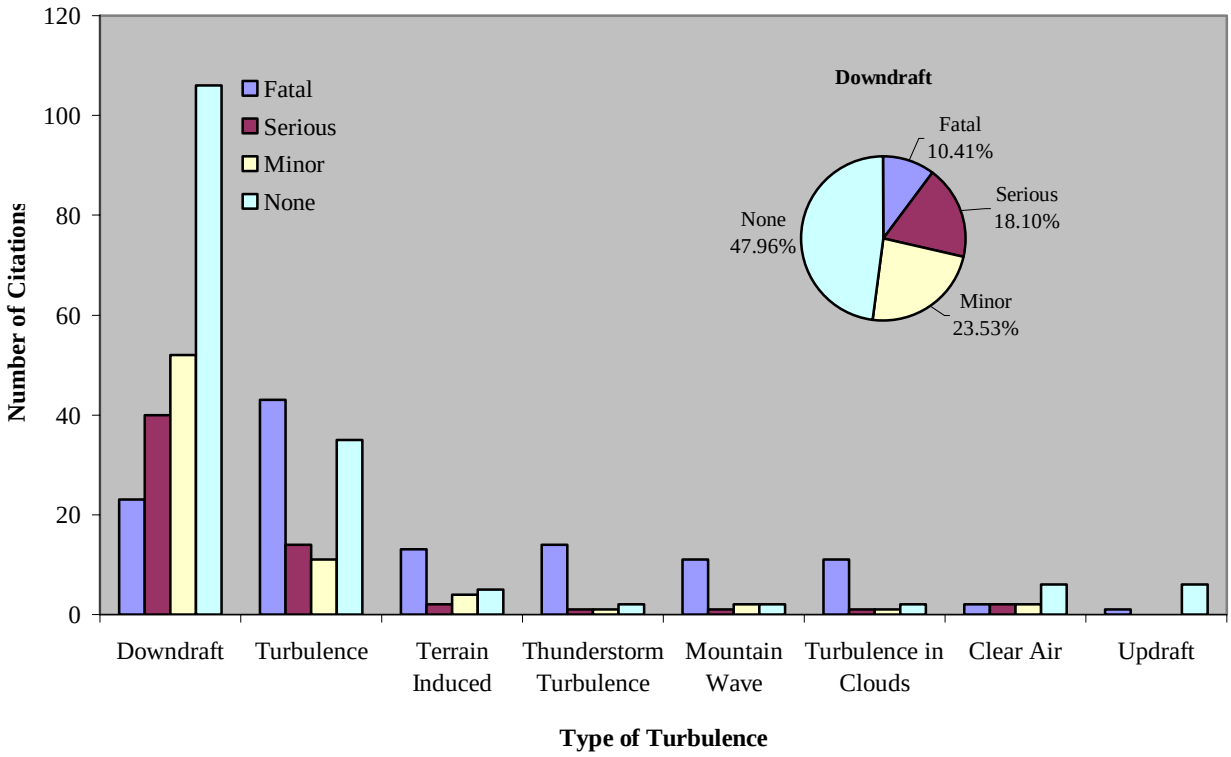


Figure 23. General Aviation Weather Turbulence Accidents by Types of Turbulence and Injury Severity

Type of Turbulence	Fatal	Serious	Minor	None	Total
Downdraft	23	40	52	106	221
Turbulence	43	14	11	35	103
Terrain Induced	13	2	4	5	24
Thunderstorm Turbulence	14	1	1	2	18
Mountain Wave	11	1	2	2	16
Turbulence in Clouds	11	1	1	2	15
Clear Air	2	2	2	6	12
Updraft	1	0	0	6	7
Total	**118**	**61**	**73**	**164**	**416**

An example of a turbulence event that resulted in a fatal injury involved a pilot operating in California. The pilot advised air traffic control that she was experiencing moderate to severe turbulence and was unable to maintain altitude. She requested the nearest airport and was given a heading and distance to the field. The pilot reported that the door popped open in flight. Shortly after, radio and radar contact were lost. A witness reported that the aircraft was in level flight and then abruptly rolled to the right, pitched forward, and continued in a nose down attitude until it experienced an in-flight breakup. Weather forecasts were for moderate to severe clear air turbulence, strong winds, scattered to broken clouds, and rain and icing conditions. The investigator cited clear air turbulence and windshear as factors to this fatal accident.

The cause was determined to be the pilot's failure to maintain an adequate airspeed after encountering turbulence, low level wind shear, and an open door.

NTSB Report Number: LAX97FA070

The majority of the events involving general aviation operations occurred during the cruise phase of flight, followed by the landing phase. Most of the fatal events also occurred during the cruise phase of flight; however the landing phase resulted in no injuries almost 75 percent of the time.

Figure 24. General Aviation Weather Turbulence Accidents by Phase of Flight and Injury Severity (Aircraft Count)

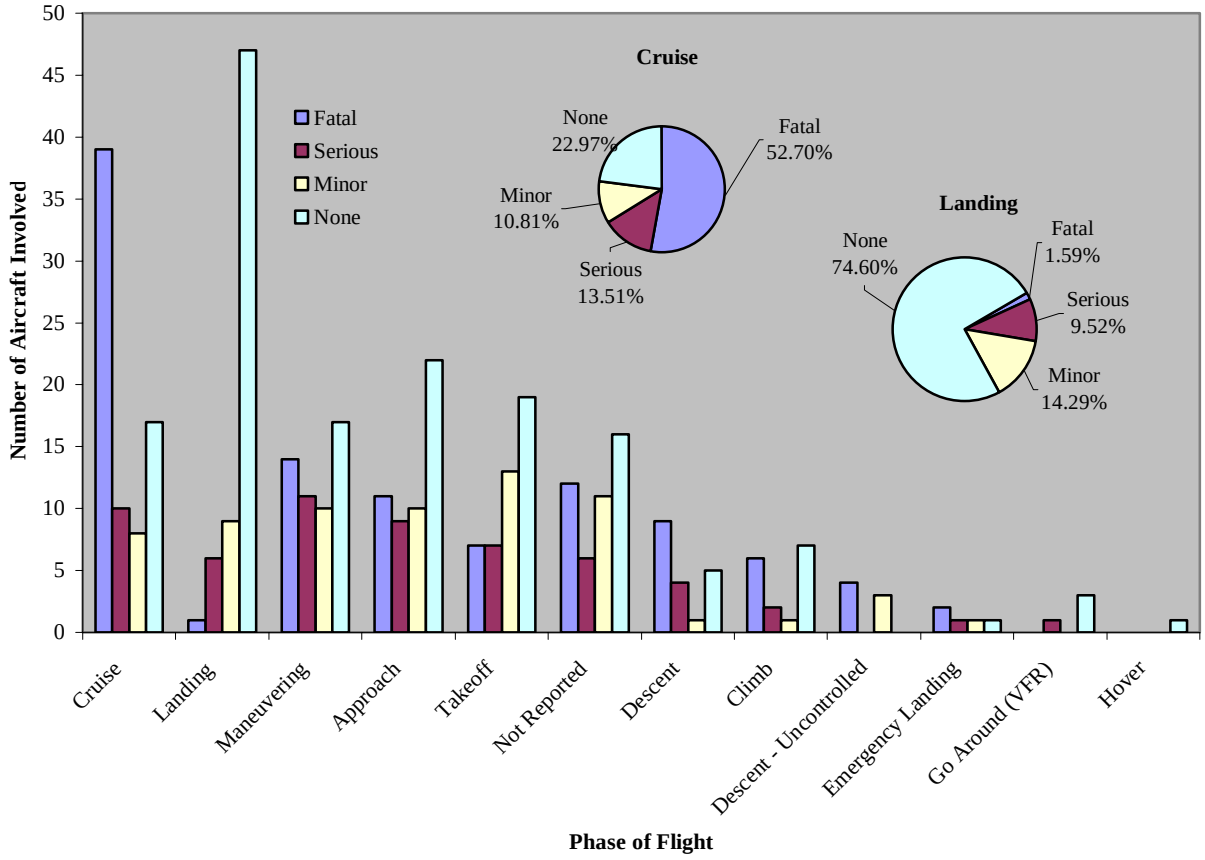


Figure 25. Fatal General Aviation Weather Turbulence Accidents by Phase of Flight

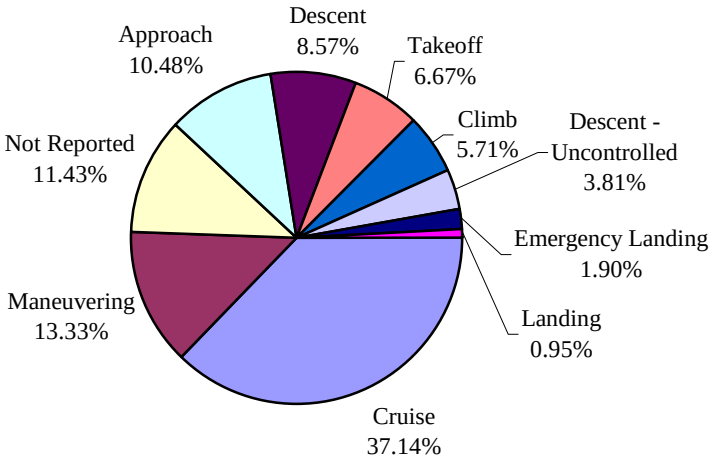


Figure 26. General Aviation Weather Turbulence Accidents – Flight Phase and Injury Severity (Aircraft Count)

Phase of Flight	Fatal	Serious	Minor	None	Total
Cruise	39	10	8	17	74
Landing	1	6	9	47	63
Maneuvering	14	11	10	17	52
Approach	11	9	10	22	52
Takeoff	7	7	13	19	46
Not Reported	12	6	11	16	45
Descent	9	4	1	5	19
Climb	6	2	1	7	16
Descent - Uncontrolled	4	0	3	0	7
Emergency Landing	2	1	1	1	5
Go Around (VFR)	0	1	0	3	4
Hover	0	0	0	1	1
Total	**105**	**57**	**67**	**155**	**384**

Part 121 – Air Carrier Review

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

From 1992 to 2001, according to the NTSB final reports, weather turbulence was identified as the cause or factor in 509 accidents (involving 511 aircraft). Part 121 operations accounted for 72 of the 509 accidents. This section will concentrate on the 72 Part 121 weather turbulence accidents.

Please note: Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have operated under FAR Part 121. Prior to March of 1997, some of these flights operated under FAR Part 135.

It is also important to note that some of the turbulence events will not be captured in this portion of the study due to the search criteria and data source used. Many of the Part 121 events in which a passenger or crew member experienced minor injuries (such as a broken nose or finger) due to turbulence will not be included in the counts presented in this publication. This circumstance does not meet the National Transportation Safety Board's definition of an accident. The majority of these events are collected in the Federal Aviation Administration Accident/Incident Data System (AIDS), which can be viewed and searched on the NASDAC website – https://www.nasdac.faa.gov.

The number of Part 121 accidents due to weather turbulence has increased from four events in 1992 to eight events in 2001.

Figure 27. Part 121 Weather Turbulence Accidents by Year

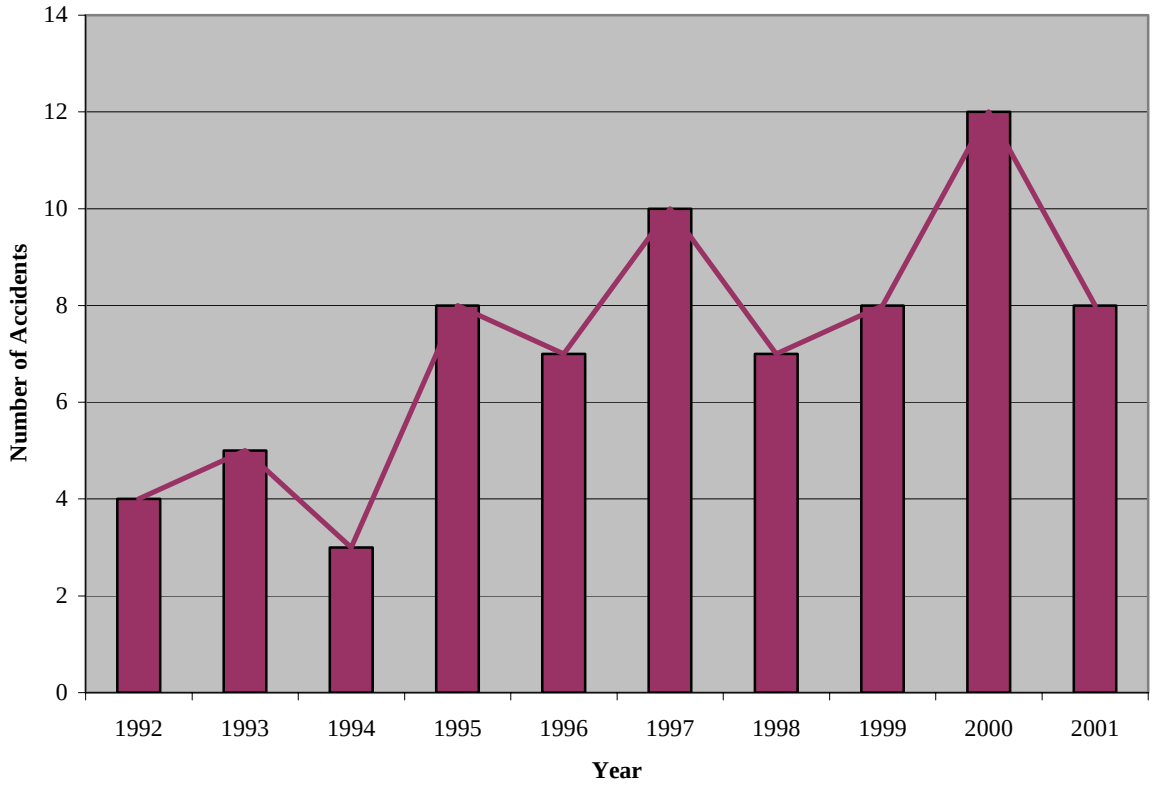


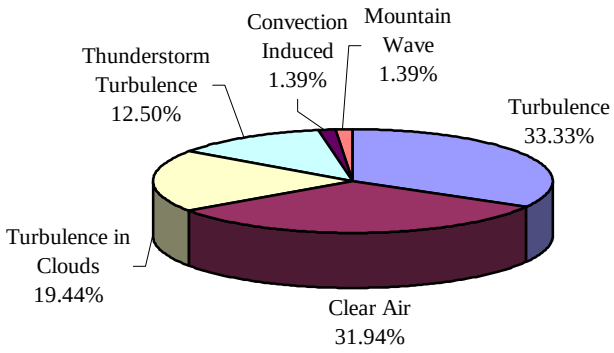
Figure 28. Part 121 Weather Turbulence Accidents - Year

Year	Number of Accidents	Percentage of Part 121 Weather Turbulence Accidents
1992	4	5.56%
1993	5	6.94%
1994	3	4.17%
1995	8	11.11%
1996	7	9.72%
1997	10	13.89%
1998	7	9.72%
1999	8	11.11%
2000	12	16.67%
2001	8	11.11%
Total	**72**	**100.00%**

The following counts are based on the number of causes and factors identified by the accident investigator.

Figure 29. Part 121 Weather Turbulence Accidents by Type of Turbulence (Citation Count)

Type of Turbulence	Number of Citations
Turbulence	24
Clear Air	23
Turbulence In Clouds	14
Thunderstorm Turbulence	9
Convection Induced	1
Mountain Wave	1
Total	**72**



Turbulence and clear air turbulence accounted for the majority of the serious injuries. Figure 29 is a depiction of the number of injuries sustained by the passengers and/or crewmembers onboard in the aircraft by the type of turbulence.

Figure 30. Part 121 Weather Turbulence Injuries by Type of Turbulence (Injury Count)

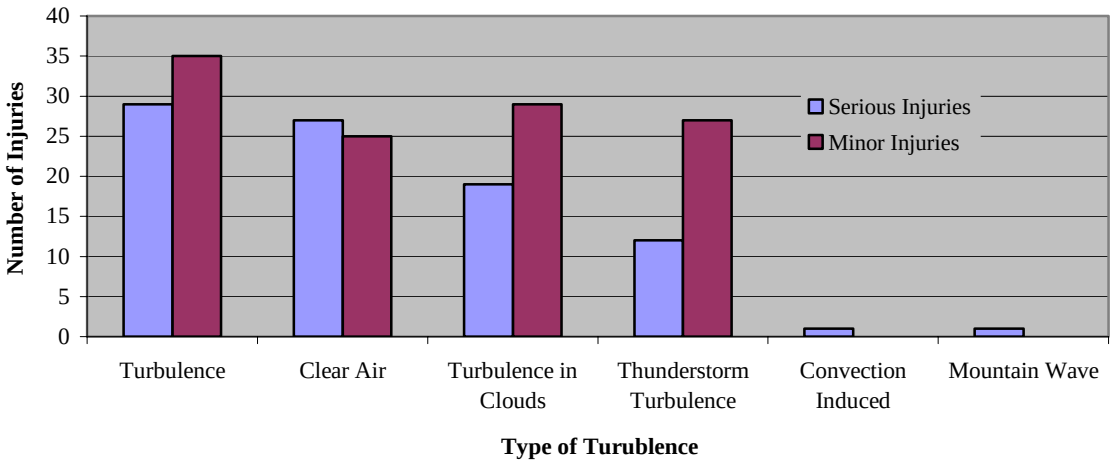


Figure 31. Part 121 Weather Turbulence Injuries - Type of Turbulence (Citation Count)

Type of Turbulence	Serious Injuries	Minor Injuries	Total Injuries
Turbulence	29	35	64
Clear Air	27	25	52
Turbulence in Clouds	19	29	48
Thunderstorm Turbulence	12	27	39
Convection Induced	1	0	1
Mountain Wave	1	0	1
Total	**89**	**116**	**205**

Seventy-one of the 72 weather turbulence accidents involving Part 121 operations from 1992 through 2001 investigated by the NTSB have resulted in serious injuries to passengers and/or crew on board the aircraft. An example of such a flight follows:

The flight was being vectored between two thunderstorm cells in Instrument Meteorological Conditions (IMC). After entering an area of visual conditions, the flight crew noticed a cumulus nimbus buildup directly ahead of the flight path. The condition had not been displayed on their radar and the cell was too close to avoid. The captain immediately made an announcement for the flight attendants, who were in the process of serving the cabin, to be seated. The flight experienced about ten seconds of severe turbulence and lost approximately 900 feet in altitude. Three of the nine flight attendants and one passenger, who did not have the seat belt fastened, were seriously injured.
The cause was determined to be an in-flight encounter with turbulence.
NTSB Report Number: CHI95LA188

The following event is an example of a Part 121 flight where the result was a substantially damaged aircraft, a seriously injured flight attendant, and a seriously injured passenger:

The flight crew received an incomplete flight release from dispatch prior to this flight. Neither a pertinent Convective SIGMET nor a tornado watch bulletin was included in the dispatch documents. During initial climb after takeoff, the flight crew noticed that they were approaching a line of thunderstorms. The captain initially planned to fly around this line, but noticed a ten-mile gap in the line that was depicted on the airplane's on-board weather radar display and decided to fly through it. Radar and weather data indicated that the airplane penetrated an extreme weather echo (VIP level 6) that likely contained a severe thunderstorm, hail, and severe to extreme turbulence. The flight attendants and passengers did not receive an adequate or timely briefing to remain seated and to prepare for the possibility of turbulence. The aft flight attendant and a passenger were seriously injured. Hail shattered the front windshield and damaged the pitot system, radome, wings, tail, and engines.
The cause was determined to be the failure of the flight crew to maintain adequate separation from hazardous meteorological conditions. Factors contributing to the accident were: (1) the failure of the air carrier to provide adequate crewmember training and guidance regarding hazardous weather encounters; (2) the failure of the flight crew to provide an adequate and timely briefing to the flight attendants regarding turbulence; and (3) the presence of hail and turbulence.
NTSB Report Number: DCA98MA045

The last example involves a substantially damaged cargo aircraft resulting in no injuries to those on board the aircraft:

During the cruise phase of flight at flight level 310, the all cargo aircraft 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 cause was determined to be an encounter with severe clear air turbulence.
NTSB Report Number: DEN93FA015

Georgia is the top state for weather turbulence involving Part 121 operations with nine events. Please note that if a state does not appear in Figure 32, it is due to zero Part 121 weather turbulence events in that state from 1992 to 2001.

Figure 32. Part 121 Weather Turbulence Accidents by State

State	Number of Accidents
Georgia	9
Florida	6
Illinois	5
California	5
Wisconsin	4
New Jersey	4
Colorado	4
Texas	3
Indiana	3
Oregon	3
New York	3
Michigan	3
Alaska	2
Missouri	2

State (Con't)	Number of Accidents
North Carolina	2
Louisiana	2
Nevada	2
New Mexico	2
North Dakota	1
Massachusetts	1
Hawaii	1
Pennsylvania	1
South Carolina	1
Tennessee	1
Kansas	1
Virginia	1
Total	**72**

Part 135 – Air Taxi and Commuter Review

FAR 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. The nonscheduled operations also include cargo planes with payload capacities of 7,500 pounds or less.

Please note: Since March 20, 1997, aircraft with 10 or more seats used in scheduled passenger service have operated under FAR Part 121. Prior to March of 1997, some of these flights operated under FAR Part 135.

From 1992 to 2001, according to NTSB final reports, weather turbulence was identified as a cause or factor in 509 accidents (511 aircraft). Part 135 operations accounted for 26 of the 509 accidents. This section will concentrate on the 26 Part 135 weather turbulence accidents.

Figure 33. Part 135 Weather Turbulence Accidents by Year

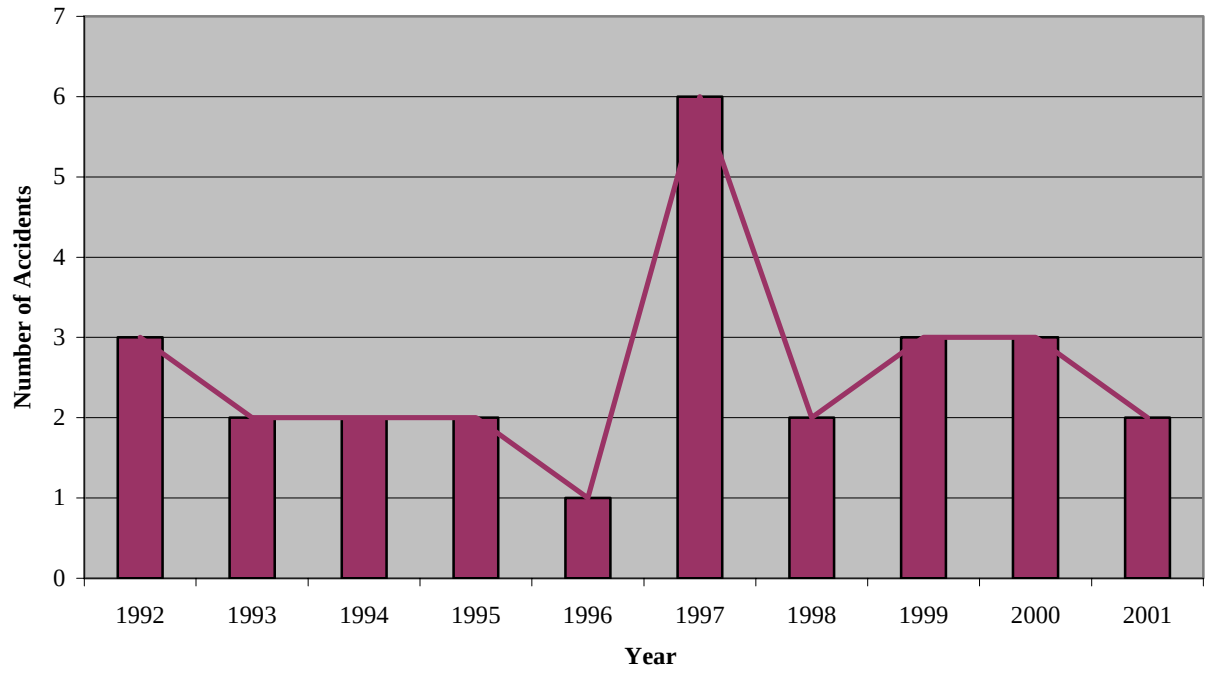


Figure 34. Part 135 Weather Turbulence Accidents – Year

Year	Number of Accidents	Percentage of Part 135 Weather Turbulence Accidents
1992	3	11.54%
1993	2	7.69%
1994	2	7.69%
1995	2	7.69%
1996	1	3.85%
1997	6	23.08%
1998	2	7.69%
1999	3	11.54%
2000	3	11.54%
2001	2	7.69%
Total	**26**	**100%**

The following counts are based on the number of causes and factors identified by the accident investigator. It is possible that a single event has more than one turbulence cause or factor cited. For the 26 aircraft involved in weather turbulence events, there are 29 turbulence-related causes and/or factors cited. Downdraft was the major weather turbulence factor involving Part 135 operations, accounting for more than 50 percent of the total.

Figure 35. Part 135 Weather Turbulence Accidents by Type of Turbulence (Citation Count)

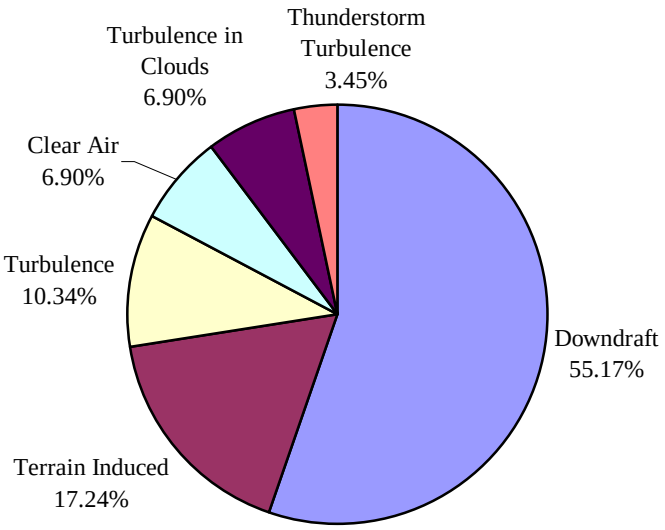


Figure 36. Part 135 Weather Turbulence Accidents – Type of Turbulence and Injury Severity (Citation Count)

Type of Turbulence	Fatal	Serious	Minor	None	Total
Downdraft	2	1	4	9	16
Terrain Induced	2	1	1	1	5
Turbulence	0	0	1	2	3
Clear Air	1	1	0	0	2
Turbulence in Clouds	2	0	0	0	2
Thunderstorm Turbulence	1	0	0	0	1
Total	**8**	**3**	**6**	**12**	**29**

An example of a Part 135 weather turbulence event involved a local sightseeing helicopter flying in mountainous terrain. The pilot encountered clouds covering the mountain pass and elected to proceed toward an alternate destination. The clouds forced the pilot to climb the helicopter to 10,500 feet MSL. The pilot allowed the airspeed to decrease, executed a turn, and encountered a downdraft. The pilot was unable to maintain the altitude and the helicopter collided with the mountainous terrain. This did not result in fatalities, but two of the passengers were seriously injured.
The cause was determined to be the pilot's poor in-flight decision by failing to attain the best rate of climb speed and exceeding the helicopter's hover performance capability. The clouds and downdraft were factors in this accident.
NTSB Report Number: LAX94LA134

Over 50 percent of the Part 135 weather turbulence events occurred in the state of Alaska. Please note that if a state does not appear in Figure 37, it is due to zero Part 135 weather turbulence events in that state from 1992 to 2001.

Figure 37. Part 135 Weather Turbulence Accidents by State (Accident Count)

State	Number of Accidents
Alaska	14
Colorado	2
Idaho	2
Utah	2
Arizona	1
Arkansas	1

State (Con't)	Number of Accidents
California	1
Hawaii	1
South Carolina	1
Texas	1
Grand Total	**26**

The majority of the 26 Part 135 accidents occurred in Cessna aircraft, followed by Piper.

Figure 38. Part 135 Accidents by Aircraft Type

Aircraft Make	Number of Accidents
Cessna	11
Piper	6
Snias	1
De Havilland-Bombardier	1
Gulfstream	1
Learjet-Bombardier	1
Maule	1
Noordn	1
Bell	1
Raytheon	1
Robinson	1
Total	**26**

Part 137 – Agricultural Operations Review

FAR Part 137 refers to agricultural aircraft operations. Agricultural aircraft operation means 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 1992 to 2001, according to NTSB final reports, weather turbulence was identified as a cause or factor in 509 accidents (involving 511 aircraft). Part 137 operations accounted for 25 of the 509 accidents. This section will concentrate on the 25 Part 137 weather turbulence accidents.

Figure 39. Part 137 Weather Turbulence Accidents by Year

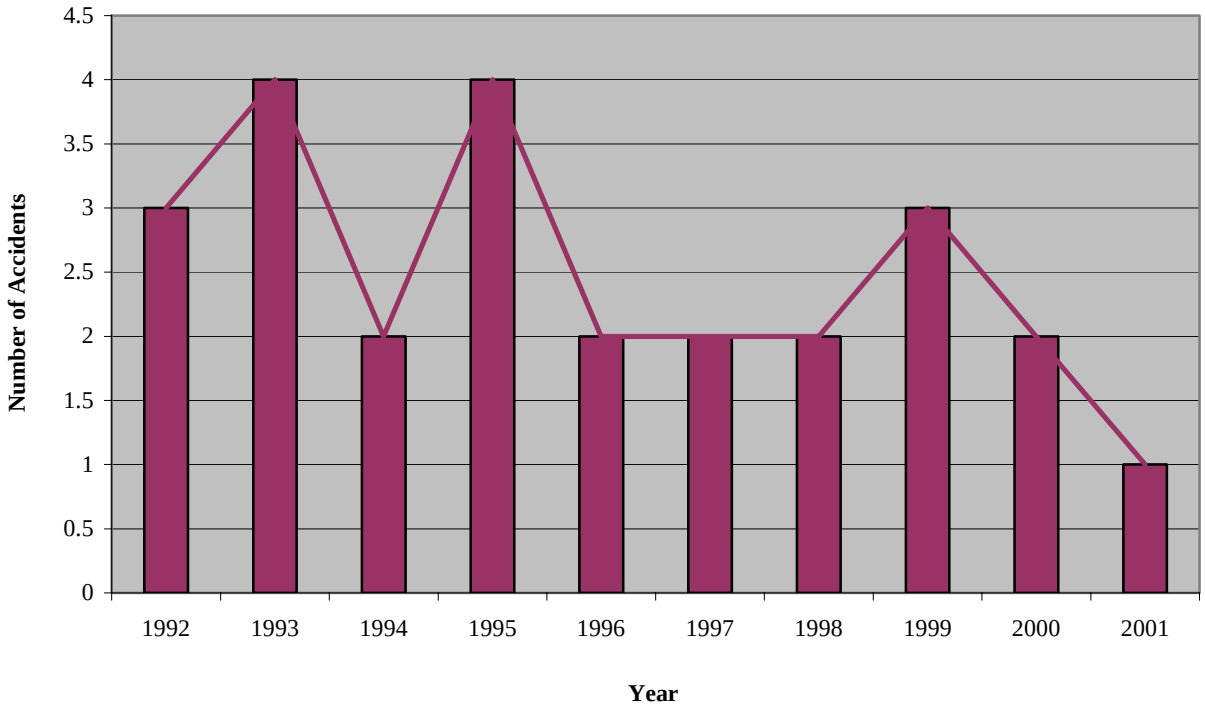
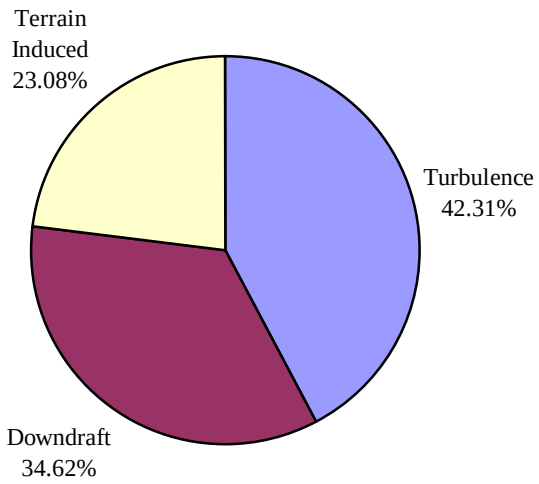


Figure 40. Part 137 Weather Turbulence Accidents – Year

Year	Number of Accidents	Percentage of Part 137 Weather Turbulence Accidents
1992	3	12.00%
1993	4	16.00%
1994	2	8.00%
1995	4	16.00%
1996	2	8.00%
1997	2	8.00%
1998	2	8.00%
1999	3	12.00%
2000	2	8.00%
2001	1	4.00%
Total	**25**	**100.00%**

The following counts are based on the number of causes and factors identified by the accident investigator. It is possible that a single event has more than one turbulence cause or factor cited. For the 25 accidents involved in weather turbulence, there are 26 turbulence-related causes and/or factors cited.

Figure 41. Part 137 Turbulence Weather Accidents by Type of Turbulence



The 25 accidents involving Part 137 operations resulted in three fatal accidents, two of which involved terrain induced turbulence. About fifty percent of these 25 accidents resulted in no injuries.

Figure 42. Part 137 Weather Turbulence Accidents by Type of Turbulence and Injury Severity (Citation Count)

Type of Turbulence	Fatal	Serious	Minor	None	Total
Turbulence	1	1	0	9	11
Downdraft	0	0	7	2	9
Terrain Induced	2	2	0	2	6
Total	**3**	**3**	**7**	**13**	**26**

An illustration of a Part 137 operation encountering turbulence involves a pilot who was completing a swath run. Following the run, the aircraft crossed over a ridge and experienced a severe downdraft. The pilot stated that he was unable to stop the aircraft's descent and collided with the terrain. The pilot, the only occupant of the aircraft, walked away with minor injuries.
The cause was determined to be the downdraft weather condition and the pilot's failure to maintain adequate clearance from the terrain during his maneuver.
NTSB Report Number: ATL95LA110

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Glossary

Accident – 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.

Fatal Injury – The NTSB defines a fatal injury as any event that results in death within 30 days of the event.

FAR Part 91 (General Aviation) – 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.

FAR Part 121 (Air Carrier) – refers to scheduled domestic airlines and cargo carriers that fly large transport category aircraft.

FAR Part 135 (Air Taxi and Commuter) – 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. The nonscheduled operations also include cargo planes with payload capacities of 7,500 pounds or less.

FAR Part 137 (Agricultural) – refers to agricultural aircraft operations. Agricultural aircraft operation means 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 event, other than an accident, associated with the operation of an aircraft that affects or could affect the safety of operations.

Serious Injury – The NTSB defines a serious injury as any injury that (1) Requires hospitalization for more than 48 hours, commencing within seven days from the date the injury was received; (2) Results in a fracture of any bone (expect simple fracture 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 affecting more than five 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 would normally require major repair or replacement of the affected component. Engine failure or damage limited to the engine if only one engine fails or is damaged, bent fairings or cowlings, dented skin, small puncture holes in the skin or fabric, ground damage to rotor or propeller blades, and damage to landing gear, wheels, tires, engine accessories, brakes, or wingtips are not considered ‘substantial damage.’