Risk Factors Associated with Weather-Related General Aviation Accidents

Safety Study

NTSB/SS-05/01

PB2005-917004
Notation 7565A

National Transportation Safety Board
Washington, D.C.

this page intentionally left blank

Safety Study

Risk Factors Associated with Weather-Related General Aviation Accidents

NTSB/SS-05/01
PB2005-917004
Notation 7565A
Adopted September 7, 2005

National Transportation Safety Board
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594

National Transportation Safety Board. 2005. ***Risk Factors Associated with Weather-Related General Aviation Accidents.*** **Safety Study NTSB/SS-05/01. Washington, DC.**

Abstract: The goal of this National Transportation Safety Board study was to better understand the risk factors associated with accidents that occur in weather conditions characterized by IMC or poor visibility ("weather-related accidents"). Safety Board air safety investigators collected data from 72 general aviation accidents that occurred between August 2003 and April 2004. When accidents occurred, study managers also contacted pilots of flights that were operating in the vicinity at the time of those accidents for information about their flight activity. A total of 135 nonaccident flights were included in the study. All nonaccident pilots voluntarily consented to interviews and provided information about their flights, their aircraft, and details about their training, experience, and demographics. Additionally, the Federal Aviation Administration provided information about pilots' practical and written test results and their previous accident/incident involvement. Statistical analyses were used to determine the relationships between study variables and accident/nonaccident status and to identify variables that could be linked to an increased risk of weather-related general aviation accident involvement. The analysis revealed several pilot- and flight-related factors associated with increased risk of accident involvement. The safety issues discussed in this report include: 1) pilot age and training-related differences, 2) pilot testing, accident, and incident history, and 3) pilot weather briefing sources and methods. Safety recommendations concerning these issues were made to the Federal Aviation Administration.

The National Transportation Safety Board is an independent Federal agency dedicated to promoting aviation, railroad, highway, marine, pipeline, and hazardous materials safety. Established in 1967, the agency is mandated by Congress through the Independent Safety Board Act of 1974 to investigate transportation accidents, determine the probable causes of the accidents, issue safety recommendations, study transportation safety issues, and evaluate the safety effectiveness of government agencies involved in transportation. The Safety Board makes public its actions and decisions through accident reports, safety studies, special investigation reports, safety recommendations, and statistical reviews.

Recent publications are available in their entirety on the Web at <http://www.ntsb.gov>. Other information about available publications also may be obtained from the Web site or by contacting:

National Transportation Safety Board
Records Management Division
490 L'Enfant Plaza, S.W.
Washington, D.C. 20594
(800) 877-6799 or (202) 314-6551

Safety Board publications may be purchased, by individual copy or by subscription, from the National Technical Information Service. To purchase this publication, order report number **PB2005-917004** from:

National Technical Information Service
5285 Port Royal Road
Springfield, Virginia 22161
(800) 553-6847 or (703) 605-6000

Contents

Acronyms and Abbreviations v

Executive Summary vii

Chapter 1: Background 1
- Historical Trends in IMC Accidents 1
- Previous Safety Board Studies of Weather-Related GA Accidents 1
- Previous Safety Board Recommendations Pertaining to Weather 3
- Other Research on Flight in IMC 4

Chapter 2: Federal Aviation Regulations Pertaining to Instrument Flight 7
- Visual Flight Rules (VFR) Minimums 7
- Training Requirements 7
- Recency Requirements 8

Chapter 3: Aviation Weather 10
- Preflight Requirements 11
- Preflight Weather Information 11
- In-Flight Weather Information 13

Chapter 4: Study Design and Methodology 14
- Case Control Methodology 14
- Study Procedures 15
  - Study Inclusion Criteria 15
  - Matching Accident and Nonaccident Flights 16
  - Identifying Pilots of Matching Nonaccident Flights 16
  - Interviewing Nonaccident Pilots 17
- Accident Data 17
- Additional Data Sources 18
  - Weather Data 18
  - Pilot History 18
- Statistical Analyses 18
  - Chi-Square Analysis 19
  - Binary Logistic Regression Analysis 20

Chapter 5: Results 21
- Description of Study Accidents 21
- Pilot Information 21
  - Accident Pilots 21
  - Nonaccident Pilots 24
  - Pilot Flight Hours 26
  - Pilot Testing History 27

Accident, Incident, and Violation History 28
Flight Information 28
Planned Length of Flights 28
Purpose of Flight 30
Aircraft Information 30
Aircraft Ownership 30
Aircraft Equipment 31
Summary of Chi-Square Analysis 31
Binary Logistic Regression Model 31
Flight Leg Length 32
Age at Private Certificate 34
Prior Accident/Incident Involvement 34
Instrument Rating 34

Chapter 6: Discussion 35
Age-Related Differences 35
Flight Training Differences 37
Testing, Accident, and Incident History 39
Airman Knowledge and Practical Test Requirements 39
Test Performance and Accident Risk 40
Accidents and Incidents 41
Pilot History of Accidents and Incidents 42
Tracking a Pilot's Testing and Accident/Incident History 42
Pilot Weather Briefing Sources and Methods 43
Summary 46

Findings 47

Recommendations 48

Appendixes
A: Previous National Transportation Safety Board Safety Recommendations 49
B: Basic VFR Weather Minimums 59
C: Evaluation of Matching Procedure 60
D: Guided Interview 62
E: Supplemental Accident Form 65
F: A Comparison of Forecast and Actual Visibility Conditions for Study Accidents 67
G: Study Accidents 69

Acronyms and Abbreviations

ADMS	Accident Data Management System
AFSS	automated flight service station
AIRMET	airmen's meteorological information
ASI	air safety investigator
ASOS	automated surface observing system
ATC	air traffic control
ATIS	automated terminal information system
AWOS	automated weather observation system
BFR	biennial flight review
CFR	Code of Federal Regulations
DUATS	direct user access terminal system
FA	area forecast
FAA	Federal Aviation Administration
FBO	fixed base operator
Flight Watch	en route flight advisory service
FSS	flight service station
GA	general aviation
HIWAS	hazardous inflight weather advisory service
IFR	instrument flight rules
IMC	instrument meteorological conditions
METAR	aviation routine weather report/meteorological aerodrome report
NEXRAD	next generation weather radar
nm	nautical miles
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PATWAS	pilots' automatic telephone weather answering system

PIREP	pilot report
PRIA	Pilot Records Improvement Act of 1996
QICP	Qualified Internet Communication Provider
SIGMET	significant meteorological information
TAF	terminal aerodrome forecast
TIBS	telephone information briefing system
TWEB	transcribed weather en route broadcast
VFR	visual flight rules
VMC	visual meteorological conditions
VOR	very high frequency omnidirectional range
WINGS	FAA Pilot Proficiency Award Program

Executive Summary

Historically, about two-thirds of all general aviation (GA) accidents that occur in instrument meteorological conditions (IMC) are fatal—a rate much higher than the overall fatality rate for GA accidents. The goal of this National Transportation Safety Board study was to better understand the risk factors associated with accidents that occur in weather conditions characterized by IMC or poor visibility ("weather-related accidents").

The study accomplished this goal using the case control methodology, which compared a group of accident flights to a matching group of nonaccident flights to identify patterns of variables that distinguished the two groups from each other. This methodology expands on previous Safety Board efforts that have typically concentrated on summaries of accident cases. The advantage of the case control methodology is that, instead of focusing on the factors that accidents have in common, and possibly being misled by characteristics common to most pilots/flights, it identifies characteristics that set accidents apart and contribute to their occurrence.

For this study, Safety Board air safety investigators (ASI) collected data from 72 GA accidents that occurred between August 2003 and April 2004. When accidents occurred, study managers also contacted pilots of flights that were operating in the vicinity at the time of those accidents for information about their flight activity. A total of 135 nonaccident flights were included in the study. All nonaccident pilots voluntarily consented to interviews and provided information about their flights, their aircraft, and details about their training, experience, and demographics. That information was compared with data that regional ASIs collected about the accident flights as part of their normal investigations. Additionally, the Federal Aviation Administration provided information about pilots' practical and written test results and their previous accident/incident involvement.

Statistical analyses were used to determine the relationships between study variables and accident/nonaccident status and to identify variables that could be linked to an increased risk of weather-related GA accident involvement. The analysis revealed several pilot- and flight-related factors associated with increased risk of accident involvement, and the recommended approaches to mitigating those risk factors are discussed in the context of three issue areas:

1. Ensuring a minimum level of proficiency for all pilots to recognize and safely respond to hazardous weather situations.
2. Identifying and providing additional support for pilots whose performance history indicates an increased risk of weather-related accidents.
3. Providing GA pilots with additional guidance regarding sources of preflight weather information.

The Safety Board emphasizes that the conclusions reached in this study are not based on a summary of accident cases, although the merits of such Board studies have proven valuable in the past. Rather, the results are based on a statistical comparison of accident and nonaccident flights that allows for the generalization of findings from this study to the wider population of GA pilots and flights that may be at risk for a weather-related accident.

The Safety Board wishes to acknowledge the significant contribution to this study by the GA pilot community. All of the pilots contacted voluntarily provided needed information concerning their flight and aviation experience, providing the control group necessary for this study.

As a result of this study, six recommendations were issued to the Federal Aviation Administration.

Chapter 1

Background

Historical Trends in IMC Accidents

The total number of general aviation (GA) accidents per year has declined over the past two decades. However, as shown in figure 1, the relative proportion of GA accidents that occur during instrument meteorological conditions (IMC) has remained fairly stable, ranging from 5 to 9 percent of annual GA accident totals. The National Transportation Safety Board has long been concerned about GA accidents that occur in poor weather or in IMC (referred to in this study as "weather-related accidents"), especially because they are far more likely to be fatal than accidents that take place in visual meteorological conditions (VMC). Over the past 20 years, about two-thirds of all IMC accidents have resulted in at least one fatality, a rate that is three times higher than the fatality rate of all GA accidents. In 2004, 103 accidents, or 6 percent of all GA accidents, occurred in IMC. Of these accidents, 70 percent were fatal, and the 147 fatalities that resulted from these accidents accounted for more than 25 percent all deaths from GA accidents in 2004.

On November 2, 2003, at 1847 central standard time, a Commander Aircraft 114TC, N6107Z, piloted by a private pilot, was destroyed during an in-flight collision with terrain at the Hutchinson Municipal Airport, Hutchinson, Kansas. The pilot was fatally injured. Night instrument meteorological conditions prevailed at the time of the accident (CHI04FA025).

Previous Safety Board Studies of Weather-Related GA Accidents

The Safety Board published reports on weather- or visibility-related GA accidents in 1968,[1] 1974,[2] 1976,[3] and 1989.[4] The 1968 study considered in detail all GA accidents

[1] National Transportation Safety Board, *An Analysis of U.S. General Aviation Accidents Involving Weather as a Cause/Related Factor 1966*, Notation 155 (Washington, DC: 1968).

[2] National Transportation Safety Board, *Special Study of Fatal, Weather-Involved General Aviation Accidents,* NTSB-AAS-74-2 (Washington, DC: 1974).

[3] National Transportation Safety Board, *Nonfatal, Weather-Involved General Aviation Accidents*, NTSB AAS-76-3 (Washington, DC: 1976).

[4] National Transportation Safety Board, *General Aviation Accidents Involving VFR Flight Into IMC,* NTSB/SR-89-01 (Washington, DC: 1989).

that occurred in 1966 and included an analysis of the weather- and pilot-related causes and factors cited in the Board's accident findings. The 1974, 1976, and 1989 studies each examined a large number of accidents sampled over several years based on common causal or contributing factors:

- The 1974 study focused on fatal GA accidents involving weather.
- The 1976 follow-up study focused on nonfatal weather-related GA accidents.
- The 1989 study considered accidents in which "VFR-into-IMC" was cited as a probable cause or contributing factor.

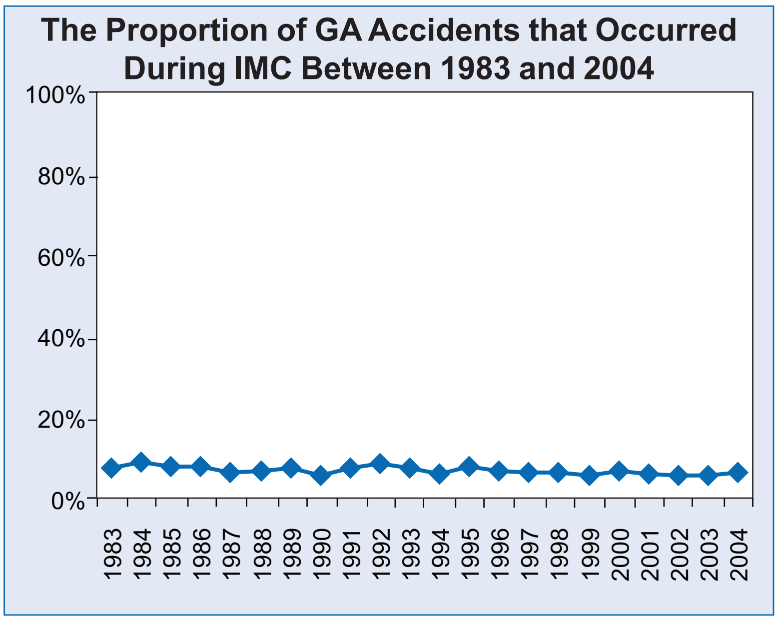

Figure 1

In each of these studies, descriptive statistics were used to characterize the accident group in terms of factors relating to the pilot, aircraft, environment, and accident circumstances. Additionally, the 1989 study included some comparisons between the VFR-into-IMC group and two other groups—one representing pilots in all GA accidents and one representing all active GA pilots.

In all of the studies, the selected group of accidents typically occurred during flights for which no flight plan had been filed. They usually involved relatively inexperienced[5] pilots with private pilot certificates and no instrument ratings. Pilots in fatal weather-related accidents were generally older than those in nonfatal accidents, and pilots involved in VFR-into-IMC accidents were older than the comparison group of all active pilots. The most common weather phenomena for fatal accidents were low cloud

[5] For example, in the 1974 study, 53 percent of pilots had less than 600 total flight hours. In the 1976 study, 84 percent of pilots had less than 100 total flight hours, and in the 1989 study, 52 percent of pilots involved in VFR-into-IMC accidents had less than 500 total flight hours compared to 41 percent of pilots in all GA accidents.

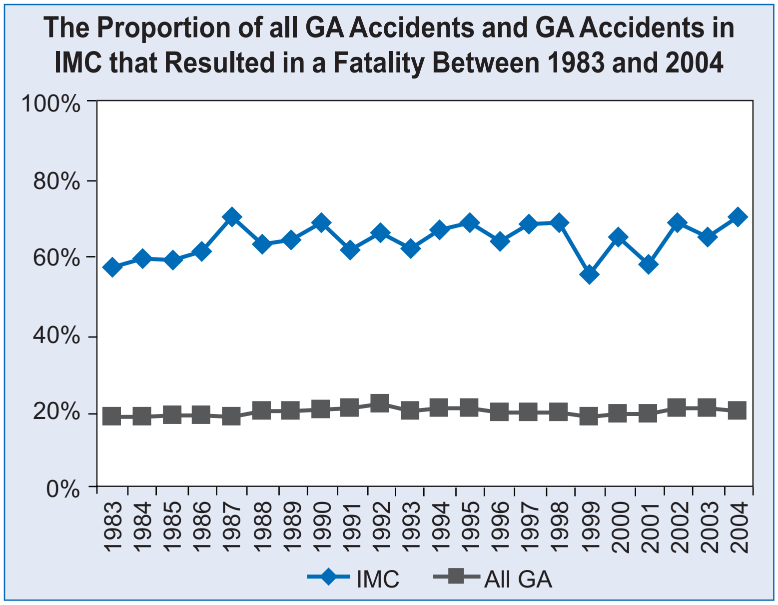

Figure 2

ceilings, fog, rain, and snow; nonfatal accidents, on the other hand, were dominated by accidents attributed to unfavorable wind.

Recommendations from the 1968, 1974, and 1976 studies were directed to the Federal Aviation Administration (FAA), the Environmental Science Services Administration,[6] and the National Oceanic and Atmospheric Administration (NOAA). Recommendations from the 1968 and 1974 studies focused on increasing pilots' knowledge and awareness of weather through training and through expansion of weather forecasting and reporting products tailored to pilots. Conversely, recommendations associated with the 1976 study emphasized hazards associated with winds during the landing phase of flight and did not pertain to conditions of reduced visibility. The 1989 report did not generate any new recommendations.

Previous Safety Board Recommendations Pertaining to Weather

In addition to the recommendations associated with safety studies, numerous recommendations concerning weather and visibility issues have resulted from accident investigations. The Safety Board's Recommendations Database shows that the Board has issued 82 recommendations relating to GA flight in IMC or visibility-related weather conditions since 1968.[7] These recommendations have addressed a variety of topics, which may be grouped into three broad areas: the collection and dissemination of weather

[6] The Environmental Science Services Administration was the predecessor agency to the National Oceanic and Atmospheric Administration.

[7] Recommendations were selected for this group if they affected GA flight in weather conditions, even if they were issued in the context of an accident that did not involve GA operations.

information, pilot training and operations, and air traffic control (ATC). Most of these recommendations were addressed to FAA, NOAA, or the National Weather Service (NWS),[8] which is part of NOAA. Appendix A summarizes these recommendations and lists each recommendation and its status.

Other Research on Flight in IMC

Weather-related accidents in general, and VFR-into-IMC accidents in particular, have generated considerable interest from other governmental agencies and the aviation research community.[9] Studies have focused on pilots' evaluations and assessments of deteriorating visibility[10] or on their flight-related decisions in the presence of weather.[11] Additionally, some researchers have suggested that a lack of good weather information during flight contributes to the incidence of weather-related accidents.[12]

Studies of accidents involving continued VFR flight into IMC often focus on pilot judgment and the factors influencing aeronautical decision-making. For instance, Jensen and Benel[13] concluded that approximately 50 percent of aviation fatalities were related to poor pilot judgment. Examples of so-called poor judgment accidents in IMC included pilots continuing VFR flight into IMC or pilots descending below a published minimum altitude while attempting an instrument approach. In some cases, these actions were intentional violations of rules or safety procedures; in other cases, they were unintentional or resulted from a misinterpretation of available information.

Other researchers have attempted to characterize the types of decision-making errors that lead pilots to make unsafe decisions. One class of decision-making error attributed to pilots in weather accidents is known as a *plan continuation error*. A plan continuation error is defined as "failure to revise a flight plan despite emerging evidence that suggests it is no longer safe."[14] For example, rather than revising the intended route

---

[8] NWS responsibilities include providing weather forecasts in support of aviation and the mission of the FAA.

[9] For a recent example, see *General Aviation Pilot Behaviours in the Face of Adverse Weather* (Australian Transport Safety Board: June 2005).

[10] D.A. Wiegmann, J. Goh, and D. O'Hare, *Pilots' Decisions to Continue Visual Flight Rules (VFR) Flight into Adverse Weather: Effects of Distance Traveled and Flight Experience,* FAA Technical Report, ARL-01-11/FAA-01-3 (2001).

[11] B. Burian, J. Orasanu, and J. Hitt, "Weather-Related Decision Errors: Differences Across Flight Types," *Proceedings of the 14th Triennial Congress of the International Ergonomics Association/44th Annual Meeting of the Human Factors and Ergonomics Society* (San Diego, CA: 2000), 1, 22-25.

[12] K. Latorella, S. Lane, and D. Garland, *General Aviation Pilots' Perceived Usage and Valuation of Aviation Weather Sources*, NASA Technical Memorandum 211443 (2002).

[13] R.S. Jensen and R.A. Benel, *Judgment Evaluation and Instruction in Civil Pilot Training,* Final Report FAA-RD-78-24 (Springfield, VA: National Technical Information Service, 1977).

[14] J. Orasanu, L. Martin and J. Davison, "Cognitive and Contextual Factors in Aviation Accidents," in E. Salas and G.A. Klein (Eds.), *Linking Expertise and Naturalistic Decision Making* (Mahwah, NJ: Lawrence Erlbaum Associates: 2001), pp. 209-225.

of flight by changing course or altitude, deviating to an alternate airport, or returning to the departure airport, pilots may opt to press on into deteriorating weather. Another type of decision-making error can occur when pilots continue visual flight into instrument conditions because they incorrectly assess the risks of the situation.[15] In these cases, pilots who appear to be intentionally engaging in risky behavior may actually be making choices that they mistakenly believe to be safe. Such diagnostic errors have been found to result in more serious accidents than have errors in aircraft control.[16] Even if pilots are able to correctly assess current weather conditions, they may still underestimate the risk associated with continued flight under those conditions, or they may overestimate their ability to handle that risk.[17]

Errors in decision-making, such as plan continuation errors or incorrect assessments of weather-related risk, may be made by pilots who are unfamiliar with the climate of the local area, who lack total and/or recent experience identifying marginal weather conditions, or who lack experience accessing or reading weather reports. For example, operational experience with weather has been found to affect weather-related decision-making and information acquisition. Targeted weather-related training programs have demonstrated some success in teaching pilots to recognize and respond to deteriorating weather conditions.[18]

It is also possible that decision-making errors and/or accident involvement are associated with more general pilot-related factors, such as total flight experience, certification-level, or risk-taking behavior. However, comparisons of pilots' experience, self-assessment of ability, and actual accident involvement have yielded conflicting results.[19] For example, low-time pilots may lack the experience they need for making decisions, whereas high-time pilots may misjudge the risk associated with weather conditions because they have successfully operated in similar weather conditions in the past. A comparison of pilot survey data with past and future accident involvement found that individual differences in attitude toward risk-taking behaviors made certain individuals more likely to be involved in an accident, regardless of experience.[20] The

---

[15] D. Wiegmann and J. Goh, *Visual Flight Rules (VFR) Flight Into Adverse Weather: An Empirical Investigation of Factors Affecting Pilot Decision Making*, FAA Technical Report ARL-00-15/FAA-00-8 (Washington, DC: FAA, 2000).

[16] D. Wiegmann and S.A. Shappell, "Human Factors Analysis of Postaccident Data: Applying Theoretical Taxonomies of Human Error," *The International Journal of Aviation Psychology,* 7 (1997): 67-81.

[17] D. O'Hare, "Pilots' Perception of Risks and Hazards in General Aviation," *Aviation, Space, and Environmental Medicine,* 61 (1990): 599-603.

[18] (a) M. Wiggins and D. O'Hare, "Expertise in Aeronautical Weather-Related Decision Making: A Cross-Sectional Analysis of General Aviation Pilots," *Journal of Experimental Psychology: Applied,* 1(4) (1995): 305-320; (b) M. Wiggins and D. O'Hare, "Weatherwise: Evaluation of a Cue-Based Training Approach for the Recognition of Deteriorating Weather Conditions During Flight," *Human Factors* 45(2) (2003): 337-345.

[19] (a) D.R. Hunter, *Airman Research Questionnaire: Methodology and Overall Results,* Report No. DOT/FAA/AM-95/27 (Washington, DC: FAA, 1995); (b) D.R. Hunter, "Retrospective and Prospective Validity of Aircraft Accident Risk Indicators," *Human Factors, 43(4)* (2001): 509-518; (c) M. Lubner, "A Risk Profile for Aviation Accidents, Incidents, and Violations Among U.S. Pilots," *Proceedings of the 9th International Symposium on Aviation Psychology* (Columbus, OH: 1997).

[20] Hunter, 2001.

same study found that previous accident involvement was associated with future accident risk. Some authors have also suggested that pilots' willingness to accept weather-related risks depends upon their tendency to focus on either the gains or losses associated with each option.[21] In addition to differences in individual decision-making style, the cost/benefit determination may be further influenced by the amount of time, money, and effort a pilot has already invested in a particular flight.

A substantial amount of existing research has used questionnaires or flight simulators in laboratory settings. Laboratory studies allow for scientific control but fail to replicate the complex demands placed on pilots conducting real-world flight operations. For example, flight simulator studies have provided a better understanding of the types of evaluation and decision-making errors that can lead to weather-related accidents. Far fewer studies have linked specific pilot, aircraft, or flight-related factors to the occurrence of actual weather-related accidents. Because of its role as the primary investigator of U.S. civil aviation accidents, the Safety Board is uniquely suited to gather information related to weather-related accidents and to identify the factors that distinguish them from successful flights.

[21] D. O'Hare and T. Smitheram, " 'Pressing On' into Deteriorating Conditions: An Application of Behavioral Decision Theory to Pilot Decision Making," *The International Journal of Aviation Psychology,* 5(4) (1995): 351-370.

Chapter 2

Federal Aviation Regulations Pertaining to Instrument Flight

Visual Flight Rules (VFR) Minimums

According to the FAA *Pilot/Controller Glossary*, instrument meteorological conditions, or IMC, are defined as "meteorological conditions expressed in terms of visibility, distance from clouds, and ceiling less than the minimums specified for visual meteorological conditions (VMC)."[22] This legal definition is used to prescribe the minimum weather conditions in which a pilot may operate an aircraft without meeting additional requirements of pilot qualification, aircraft equipment, and communication. These minimums account for altitude in relation to terrain and obstructions, time of day, and location in relation to areas of high air traffic density, such as airports. An example of criteria defining VMC are 3 statute miles flight visibility and a clearance of 1,000 feet above, 500 feet below, and 2,000 feet horizontal distance from clouds. Meteorological conditions are also commonly referred to as either VFR (visual flight rules) or IFR (instrument flight rules) in reference to the regulations that apply to pilots who are operating under those conditions.

On March 21, 2004, about 2050 eastern standard time, a Piper PA-32R-301, N8173U, was destroyed when it impacted mountainous terrain while in cruise flight near Harlan, Kentucky. The cerficated private pilot and five passengers were fatally injured. Instrument meteorological conditions prevailed near the accident site (NTC04FA092).

Training Requirements

Because of the unique demands related to safely managing weather, the FAA has established knowledge and training requirements for pilots to help them recognize and respond to weather hazards. All pilot applicants—regardless of certificate level—must receive training in how to avoid potential weather hazards when possible, and how to safely respond to weather hazards if they are encountered. These training requirements include the recognition and avoidance of hazardous weather, preflight actions related to

[22] Basic VFR weather minimums as defined in 14 *Code of Federal Regulations* (CFR) 91.155 are presented in appendix B.

the procurement and use of aeronautical weather reports and forecasts, and aeronautical decision-making and risk management. For instrument-rated pilots, this training is meant to provide the additional knowledge and skills needed for safe flight in IMC. Conversely, the goal of instrument flight training for VFR-only pilots is to enable them to maintain control of an aircraft while making a course reversal or diversion if they inadvertently enter clouds. Specifically, private pilot applicants who are not instrument rated must have logged a minimum of 3 hours of flight training on the control and maneuvering of an airplane solely by reference to instruments, including straight and level flight, constant airspeed climbs and descents, turns to a heading, recovery from unusual flight attitudes, radio communications, and the use of navigation systems/facilities and radar services appropriate to instrument flight. Commercial pilot applicants who are not instrument rated must have logged a minimum of 10 hours of similar instrument training.[23]

Because aircraft used in recreational and sport operations are typically not equipped for instrument flight, requirements for the recreational and sport pilot certificates do not include flight training or proficiency standards for flight by reference to aircraft instruments. Consequently, pilots holding recreational pilot or sport pilot certificates are prohibited from operating aircraft unless they maintain at least 3 statute miles visibility and visual contact with the surface.[24] Additionally, recreational pilot certificate holders may not operate an aircraft at night with less than 5 statute miles visibility, and sport pilot certificate holders may not operate an aircraft at night.

In order to pilot an aircraft on an IFR flight plan in IMC, private pilot and commercial pilot certificate holders must add an instrument rating to their pilot certificates by completing additional training and passing both knowledge and practical tests. Instrument rating applicants are required by *14 Code of Federal Regulations* (CFR) 61.65 to also receive additional ground training in how to obtain and use aviation weather reports and forecasts, the forecasting of weather trends based on that information and on their personal observation of weather conditions, the safe and efficient operation of aircraft under instrument flight conditions, the recognition and avoidance of critical weather situations, and aeronautical decision-making and judgment. The flight requirements of the instrument rating include 40 hours of actual or simulated instrument flight, including at least 15 hours of instrument flight training.[25]

Recency Requirements

Like any complex skill, flying an aircraft solely by reference to aircraft flight instruments requires periodic practice to maintain proficiency. Pilots with an instrument

---

[23] Title 14 CFR 141, Appendix D, requires that commercial pilot training conducted by a certificated flight school include 5 hours of training in the same category and class of aircraft. Commercial pilot applicants trained under this part must either hold an instrument rating or be concurrently enrolled in an instrument pilot course.

[24] Title 14 CFR 61.101 and Title 14 CFR 61.315, respectively.

[25] Title 14 CFR 141, Appendix C.4, requires pilots trained at a certificated pilot school to have a minimum of 35 hours of instrument training if the course is for an initial instrument rating or 15 hours of instrument training if the course is for an additional instrument rating.

rating on their private pilot or commercial pilot certificates must therefore meet instrument flight recency requirements in order to operate aircraft in instrument conditions. Title 14 CFR 61.57 states that no person may act as pilot-in-command under IFR or in weather conditions less than the minimums prescribed for VFR unless, within the preceding 6 calendar months, that person has conducted at least 6 instrument approaches, holding procedures, and intercepting and tracking courses through the use of navigation systems in actual or simulated instrument conditions. Pilots who do not meet this requirement have an additional 6 months after the prescribed time to meet the requirement, but may not act as pilot-in-command under IFR. Pilots who do not meet the requirement after that must pass an instrument proficiency check given by an authorized instructor, examiner, or check pilot.

Even though they are subject to an initial certification requirement, non-instrument-rated pilots are not currently required to receive recurrent instrument flight training, nor are they required to periodically demonstrate proficiency in flight by reference to instruments. All pilots *are* subject to 14 CFR 61.56, which specifies that, to act as pilot-in-command of an aircraft, they must have satisfactorily completed a flight review during the previous 24 months.[26] That review—commonly referred to as a biennial flight review or BFR—must include a minimum 1 hour each of ground and flight instruction covering general knowledge, operating rules, and procedures. The instructor giving the flight review is free to determine the content; therefore, the BFR may or may not include a demonstration of the weather knowledge and instrument flight skills required for initial certification.

[26] Title 14 CFR 61.56 specifies several additional ways for pilots to satisfy the flight review requirement, such as a practical test for an additional certificate or rating, a pilot proficiency check, or recurrent training, such as the FAA voluntary Pilot Proficiency Award Program (WINGS).

Chapter 3

Aviation Weather

Over the years, the measuring and reporting of aviation weather conditions has shifted from human observations to the use of automated systems. For example, upper-air weather data collection that once relied on sounding balloons and pilot reports (PIREP) has been supplemented by information gathered from wind profilers and aircraft equipped with instruments that automatically downlink weather observations. In addition, manual surface observations have now been augmented or replaced by the automated surface observing system (ASOS) and the automated weather observing system (AWOS). Established in the 1990s, ASOS and AWOS systems are now installed at more than 1,500 airports in the United States.

Radar and satellites have also become major sources of weather information. In the 1980s and 1990s, using Doppler technology, the NWS developed next-generation radar (NEXRAD), which provides advanced and detailed information about precipitation and winds. Weather satellites provide additional information in the form of visible, infrared, and other images that are made available on a near-real-time basis to NWS and FAA facilities.

On February 11, 2004, about 2110 eastern standard time, a Piper PA-28-180, N6473J, collided with trees and the ground during approach to Bacon County Airport, Alma, Georgia. Instrument meteorological conditions prevailed. The private pilot, the pilot-rated passenger, and the rear-seated passenger received fatal injuries, and the airplane sustained substantial damage (ATL04FA075).

Pilots' use of weather information for flight-planning and decision-making has also changed greatly over the years. Up until the late 1960s, most pilots planned their flights with the aid of face-to-face weather briefings from trained FAA personnel working at flight service stations (FSS). In the 1970s, telephone briefings from FSS and prerecorded weather information like the telephone information briefing service (TIBS) and the pilots' automatic telephone weather answering system (PATWAS) became commonplace. In the cockpit, pilots gained access to radio broadcasts of airport information, including current weather conditions, using the automatic terminal information service (ATIS). The 1970s also saw the advent of in-flight weather information like the en route flight advisory service ("Flight Watch"), transcribed weather broadcasts (TWEB), and the hazardous in-flight weather advisory service (HIWAS).

Today, many pilots receive preflight weather briefings via computer using the FAA direct user access terminal system (DUATS). Additionally, Internet websites and computer terminals displaying live radar and graphical weather data are available at airports and fixed base operators (FBOs) to support flight planning with supplemental weather information. For local and en route applications, real-time weather information from ASOS has joined many of the existing in-flight weather information sources.

Most preflight and in-flight weather briefing services employ text-based or audio-based products like aviation routine weather reports (METAR), area forecasts (FA), terminal aerodrome forecasts (TAF), airmen's meteorological information reports (AIRMETs), and significant meteorological information reports (SIGMETs). Additionally, numerous graphical products are now available to pilots. For example, surface analysis and weather depiction charts portray recent atmospheric pressure patterns and surface weather observations from across the United States. Radar summary charts provide information about the location and intensity of thunderstorms and other forms of precipitation, and low-level prognostic charts provide forecast information pertaining to IMC, turbulence, and icing for 12- and 24-hour periods. Graphic products like these, as well as radar and satellite images, are available to pilots on the ground, and new services are making them available in the cockpit with the aid of datalink or satellite communications and advanced multifunctional displays.

Preflight Requirements

Title 14 CFR 91.103 requires that all pilots, "before beginning a flight, become familiar with all available information concerning that flight." Specific examples of such information are airport elevation and runway lengths, aircraft takeoff and landing distances, and aircraft gross weight. Pilots of IFR flights and non-local flights must also be familiar with weather reports and forecasts, fuel requirements, and alternatives available if the planned flight cannot be completed. When considered with 14 CFR 91.3, which stipulates that pilots-in-command are "directly responsible for, and the final authority as to, the operation of" their aircraft, pilots are solely responsible for knowing everything there is to know about the weather along their planned route of flight.

Preflight Weather Information

Preflight weather information enables pilots to prepare for conditions they may encounter during flight, or to decide that they are not qualified to fly in the reported conditions. Unlike regulations governing Parts 121 and 135, which limit operators to the use of "approved" weather sources,[27] Part 91 regulations do not specify a particular source

[27] According to the FAA *Air Transport Operations Inspectors Handbook* (8400.10), "for all operations conducted under Parts 121 and 135, weather reports either must be prepared by the National Weather Service (NWS) or by sources approved by the NWS or Federal Aviation Administration (FAA)." These sources include NWS offices, FAA Flight Service Stations, Automated Surface Observations, and certain Qualified Internet Communication Providers (QICP).

of weather information for GA pilots. The FAA and NWS provide numerous sources of weather information to pilots, including FSS telephone briefings, DUATS, and Internet website services such as <http://www.aviationweather.gov>. Commercial providers also offer data and services, such as satellite weather or flight planning software packages that include weather information.

In its *Instrument Flying Handbook* (FAA-H-8083-15), the FAA suggests that, in preparing for an IFR flight, pilots should call an automated flight service station (AFSS) to obtain a weather briefing. A "standard" preflight briefing is meant to provide pilots with sufficient weather information to prepare for their flights, and is defined by FAA Advisory Circular AC00-45E as comprising the following components:

1. **Adverse conditions.** Meteorological or aeronautical conditions reported or forecast that may influence a pilot to alter the proposed flight.
2. **VFR flight not recommended.** VFR flight proposed and sky conditions or visibilities present or forecast, surface or aloft, that, in the judgment of the AFSS/FSS briefer, would make flight under VFR doubtful.
3. **Synopsis.** A brief statement describing the type, location, and movement of weather systems and/or air masses that might affect the proposed flight.
4. **Current conditions.** A summary from all available sources reporting weather conditions applicable to the flight.
5. **En route forecast.** A summary from appropriate data forecast conditions applicable to the proposed flight.
6. **Destination forecast.** Destination forecast that includes significant changes expected within 1 hour before and after the expected time of arrival.
7. **Winds aloft.** Forecast winds aloft for the proposed route; temperature information on request.
8. **Notices to airmen.** A notice containing information concerning the establishment, condition, or change in any component of, or hazard in, the National Airspace System.
9. **ATC delays**. Any known ATC delays and/or flow control advisories that may affect the proposed flight.
10. **Request for PIREP.** A request made if a report of actual in-flight conditions would be beneficial or when conditions meet the criteria for solicitation of PIREPs.
11. **Flight Watch.** The availability of in-flight weather information (for example, Flight Watch) for weather updates.
12. Any other information the pilot requests (for example, military training activity along the route of flight).

In-Flight Weather Information

Each time they fly, pilots must continuously evaluate in-flight weather to identify conditions that could potentially affect the safety of their flights. In so doing, pilots must integrate what they see outside the cockpit with data presented by aircraft instruments and any additional information they receive from ATC, weather reporting facilities, and other pilots. Pilots must then compare that information against their expectations based on the forecast weather.

Pilots without a current instrument rating, or those flying aircraft certified for VFR flight only, must base their decisions on the need to maintain minimum VFR cloud clearances at all times. A pilot may be able to change altitude or deviate from the planned route of flight in order to maintain VFR requirements. If not, the pilot must either turn back or find a suitable alternate route or destination.

Because they are permitted to operate in degraded weather conditions, instrument-rated pilots operating on IFR flight plans are more concerned with avoiding hazards like icing, turbulence, and embedded thunderstorms that they may encounter when flying in the clouds. Detection and avoidance of in-flight weather hazards require pilots either to use weather avionics like radar or lightning detection equipment or to communicate with ATC or Flight Watch to obtain this information. Pilots can communicate directly with most local FSSs through Flight Watch or HIWAS, or if controller workload allows, request weather information through ATC. Recently, aircraft-based equipment and radio communications have begun to merge with avionics capable of displaying weather data, such as METARs, TAFs, FAs, AIRMETS, SIGMETS, and PIREPs transmitted through either a ground-based array or a satellite network.[28]

[28] For an example of a system that combines datalinked traffic, weather, and terrain information with advanced aircraft displays, see the FAA's Alaska Capstone project, <http://www.alaska.faa.gov/capstone/>.

Chapter 4

Study Design and Methodology

The goal of this study was to identify factors that are predictive of accident risk for GA pilots flying in weather-related conditions characterized by poor visibility, like IMC or marginal VMC.[29] This goal was accomplished by comparing a set of weather-related GA accidents to a corresponding set of nonaccident flights that took place under similar weather conditions. This approach, referred to as the case control methodology, allows for a determination of the odds of involvement in accidents based on identified risk factors. The advantage of this approach is that, instead of focusing on what accidents have in common, and possibly being misled by characteristics common to most pilots/flights, it identifies characteristics that set accidents apart and contribute to their occurrence.

On January 10, 2004, about 1840 central standard time, a Cessna 182P, N5787J, was destroyed during an in-flight collision with trees and terrain 7 1/2 miles southwest of the Baudette International Airport, Baudette, Minnesota. Night instrument meteorological conditions prevailed at the time of the accident. The non-instrument-rated pilot and passenger sustained fatal injuries (CHI04FA055).

Case Control Methodology

The case control methodology is commonly used in epidemiological research to compare a group of interest, such as people with a certain disease (that is, "cases") with a group of individuals from the same population who do not exhibit the disease (that is, "controls"). Control groups may be randomly selected from within the population of interest or may be selected to "match" cases on certain variables, such as age, sex, or exposure to potential risk factors.

In the aviation domain, the case control methodology has been used in only a handful of studies. For example, one study compared characteristics of accident pilots to a larger pilot sample and found that accident pilots were more likely to have medical problems than the

[29] Marginal VMC is used to refer to conditions in which visibility is between 3 and 5 miles or when ceiling height is between 1,000 and 3,000 feet.

overall pilot population.[30] A similar approach was used to a lesser extent in the Safety Board's 1989 safety study, which found that pilots involved in VFR-into-IMC accidents were older and less likely to have an instrument rating than a sample of all active GA pilots.[31]

Other case control studies have gathered preexisting survey or accident data from groups of pilots and then categorized the data by a variable of interest, like the pilot's involvement in an accident or an accident's fatal or nonfatal outcome. For example, one study, which compared fatal-to-the-pilot GA crashes to those in which the pilot survived, found that aircraft fires, off-airport locations, nighttime flight, and IMC were linked to pilot fatality.[32] Another study examining predictors of pilot fatality among weather-related GA accidents resulted in similar findings.[33]

One challenge associated with using historical accident records or surveys is that the data they contain may be incomplete or inadequate to address the research goals. The present study addressed that challenge by identifying variables of interest a priori, which facilitated more consistent and complete data collection from cases and controls.

Study Procedures

Study managers from the Safety Board's Office of Research and Engineering worked closely with air safety investigators (ASI), air traffic specialists, and Safety Board meteorologists from the Office of Aviation Safety. When GA accidents occurred during the study time frame (August 2003 through April 2004), ASIs used preliminary information to determine if the accident met the study inclusion criteria and notified the study managers accordingly. Study managers also monitored FAA incident/accident daily reports to identify additional qualifying accidents.

Study Inclusion Criteria

Before data collection began, study managers established a set of criteria to guide the selection of accident cases. Study inclusion criteria were based on initial observations of the weather at the time of the accident and characteristics of the accident flight. Accidents were selected if they involved a GA operation and happened in either IMC or marginal VMC. Also included were accidents that appeared to have involved spatial disorientation, loss of control, or collision with terrain or object due to a lack of visual references or encounter with weather.

---

[30] C.R. Harper, "Physical Defects of Civilian Pilots Related to Aircraft Accidents," *Aerospace Medicine,* 35 (1964): 462-464.

[31] NTSB/SR-89-01.

[32] G. Li and S.P. Baker, "Correlates of Pilot Fatality in General Aviation Crashes," *Aviation, Space, and Environmental Medicine,* 70 (1999): 305-309.

[33] J. M. Price and L.S. Groff, "Risk Factors for Fatal General Aviation Accidents in Degraded Visual Conditions," *Proceedings of the 13th International Symposium on Aviation Psychology* (Oklahoma City, OK, 2005), 469-474.

Matching Accident and Nonaccident Flights

Once a candidate accident was identified, staff began to identify and locate matching nonaccident flights based on the factors listed below.

- Weather conditions
- Location (within 30 miles of accident)
- Time (within 30 minutes of accident)
- Rules of flight
- Number of engines
- Engine type

For example, if an accident flight was operating under VFR, corresponding nonaccident flights were selected from other VFR flights operating in similar conditions and in similar aircraft near the accident site. A subsequent review of data from accident and nonaccident flights, presented in appendix C, confirmed the success of the matching procedure.

Identifying Pilots of Matching Nonaccident Flights

If the accident flight was operating on an IFR flight plan, nonaccident aircraft were identified with the use of commercially available flight tracking software.[34] Information presented by the software is based on composite radar data used by the FAA for system-wide traffic monitoring and flow control. As shown in figure 3, the software provided graphical displays of aircraft radar data, as well as such weather products as NEXRAD radar. After an accident occurred, Safety Board staff used the software to review flight traffic and weather information around the accident site at the time of the accident and to obtain registration numbers of matching nonaccident flights.

Because the software depicted only flights receiving ATC radar services, an alternative procedure was used for accident flights that were operating under VFR. For those flights, study managers telephoned airports and FBOs within a 30-mile radius of the accident and along the accident route of flight to identify matching aircraft. Airport and FBO employees were informed about the study and its purpose and were asked if they were aware of any aircraft that had arrived, departed, or passed through the area around the time of the accident. An effort was also made to identify pilots who intended to fly but chose not to because of the weather. For VFR accidents, multiple inquiries were typically necessary to identify appropriate nonaccident pilots. In addition to telephone inquires, primary radar was used when necessary to determine whether *any* other aircraft had passed through the area.

[34] Flight Explorer Professional (Version 4.6) [Computer software]. Alexandria, VA: Flight Explorer, Inc.

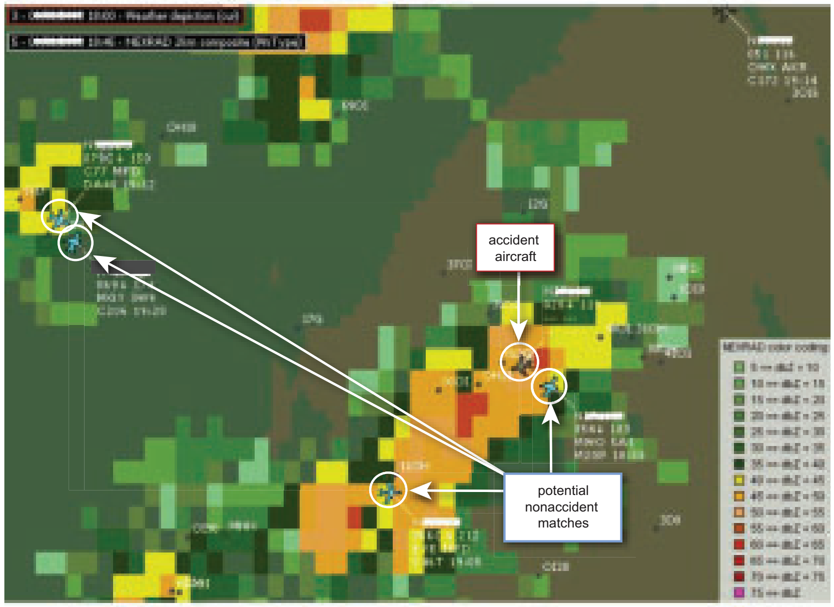

Figure 3. Screenshot of flight tracking software depicting weather, an accident aircraft, and potential nonaccident matches.

Interviewing Nonaccident Pilots

Once candidate nonaccident aircraft matches were identified, a study manager contacted the registered owners via telephone. Aircraft owners were informed about the purpose of the study and allowed either to accept or decline participation. If the owner was not piloting the aircraft during the flight of interest, or if the aircraft was being operated for rent, the flying pilot was identified and contacted. In most cases, study managers were able to identify and interview pilots within 72 hours of the accident flight.

Of the aircraft pilots who were contacted, 100 percent volunteered to participate in a structured interview designed to elicit details of their flights, available equipment in the aircraft they were flying, and their previous flight experience. A copy of the interview form is included in appendix D. Much of the information collected from nonaccident pilots corresponded to information typically collected as part of Safety Board accident investigations. No personally identifiable information pertaining to nonaccident pilots was retained after the collection of study-related data.

Accident Data

Every effort was made to assemble matching data concerning both the accident and nonaccident flights. Safety Board accident investigators routinely collect a core set of factual data for aviation accident investigations and for populating a census of all U.S. civil aviation accidents. This census, known as the Aviation Accident/Incident Database, includes details about accident events (for example, time, location, and weather conditions), aircraft (for example, model type, inspection records, and engine specifications), and pilots (for example, certificates, ratings, and flight hours flown).

Most of the data needed for this study were available using the Aviation Accident/Incident Database. For data not typically collected during accident investigations, the investigator completed a supplemental form and sent it to the study managers. The supplemental form, shown in appendix E, requested such information as the number of instrument instruction hours received and whether the aircraft had various equipment used to display navigation and weather information.

Additional Data Sources

Weather Data

To determine the forecast weather conditions for each accident, Safety Board meteorologists requested weather products that were released immediately before the accident airplane's departure time for the region surrounding the accident location. The actual conditions at the time and location of the accident were determined from the Safety Board factual report associated with the accident. (As part of all factual reports, investigators identify the "basic weather" conditions as either IMC or VMC.) A subsequent analysis, described in appendix F, found that in many cases, the weather at the time of the accident was similar to forecast conditions.

Pilot History

FAA records were used to obtain a variety of historical data for both accident and nonaccident pilots, including previous accidents, incidents, and violations, as well as the results of all knowledge and practical tests. Testing records included the type (for example, private, instrument, or commercial), date, and outcome (pass or fail) of each practical and knowledge test taken by a pilot. Practical test records included each test attempted, the outcome of each test, and the flight hours reported by the applicant at the time of the test. Knowledge test reports were copies of the results presented to test applicants, which typically include the number of tests attempted and the percentage score for the most recent attempt.

Additional pilot data, such as certificates, ratings, and total flight hours reported when pilots renew their medical certificate, were also obtained from the FAA Airman's Registry. This information was used to substitute for missing data (for example, when log books were destroyed in an accident.)

Statistical Analyses

Study analyses involved initial comparisons of the accident and nonaccident groups with regard to individual variables of interest, followed by development of a multivariate prediction model. Using statistical methods typical of case control studies, initial comparisons were conducted using chi-square analyses, and the multivariate prediction model was developed using binary logistic regression. All statistical analyses were conducted using the SPSS statistical package.[35]

Chi-Square Analysis

Data obtained from accident flights (cases) and from matching nonaccident flights (controls) were used to compare accident risk based on factors specific to the pilot, flight, and aircraft.[36] Chi-square tests were used to determine the extent to which accidents and nonaccidents differed on individual variables. Chi-square is a statistical test that can be used to determine whether two or more samples differ significantly with respect to the proportional distribution of a given characteristic or quality. Tests of statistical significance provide a measure of the probability that a particular finding was due to "chance." If that probability is found to be very low (for example, 5 percent or less), the finding is considered statistically significant and thereby unlikely due to random differences. Statistical significance tests are sensitive to the number of observations included in the study sample, as well as to the size of any observed difference(s).

In the context of this study, chi-square statistics were used to determine whether the study accident and nonaccident groups were different enough with regard to variables of interest to suggest that study results represent GA weather accidents in general.

The following variables were selected for the chi-square analysis:

Pilot Information

- Pilot age at the time of the accident
- Pilot age at the time of initial private certification
- Years as pilot
- Pilot highest certification level and instrument rating
- Pilot flight hours
- FAA knowledge test performance
- FAA practical test performance
- Accident/incident history
- Violation history

Flight Information

- Planned length of flight
- Purpose of flight

[35] SPSS for Windows, Rel. 13.0. 2004. Chicago: SPSS Inc.

[36] A table containing data used in this study is available in the NTSB Docket Management System.

Aircraft Information

- Aircraft ownership
- Aircraft equipment

Binary Logistic Regression Analysis

Binary logistic regression was used to identify the variables that were most predictive of accident involvement and to develop an overall accident prediction model. Binary logistic regression evaluates the combined effect of a set of predictor variables on a dichotomous outcome variable (for example, accident or nonaccident status). One strength of binary logistic regression is that the results not only indicate which variables are associated with accident involvement, but also provide an estimate of the relative risk associated with different levels of a given predictor variable—for example, the accident risk associated with flights of various lengths.[37] For this study, predictor variables were selected for inclusion in the regression model based on the initial findings from the chi-square tests, as well as on hypothesized relationships between specific variables and weather-related accidents.

[37] For a more detailed discussion of binary logistic regression, refer to the following: (a) D. Hosmer and S. Lemeshow, *Applied Logistic Regression,* 2nd ed. (New York: Wiley and Sons, 2000) or (b) B.G. Tabachnick and L.S. Fidell, *Using Multivariate Statistics*, 3rd ed. (New York: Harper Collins, 1996).

Chapter 5

Results

Description of Study Accidents

Study data were collected for GA accidents that occurred between August 1, 2003, and April 30, 2004,[38] that appeared, at the time of initial notification, to involve hazardous weather or visibility-related factors. A total of 72 accidents met the predefined selection criteria and were selected for the study.[39] Of these, 78 percent were fatal accidents that resulted in a total of 108 fatalities.

On December 7, 2003, about 1708 Pacific standard time, a Piper PA-28R-200, N16264, collided with hilly terrain about 6 miles southwest of Chino Hills, California. The private pilot and passenger were fatally injured and the airplane was destroyed. Instrument meteorological conditions prevailed in the accident area, and no flight plan had been filed (LAX04FA061).

Figure 4 shows the distribution of study accidents by month and figure 5 by time of day. About 41 percent of accidents occurred at night and 59 percent during daylight. Additionally, about 56 percent were operating on an instrument flight plan and 44 percent operated under VFR. A review of the narrative data available for the 72 study accidents showed that 7 occurred during takeoff or climb, 23 during cruise flight, 17 during descent or maneuvering flight, and 25 during approach, landing, or go-around (figure 6).

Pilot Information

Accident Pilots

Accident pilots ranged in age from 23 to 81, with a mean age of 53, and all pilots but one were male. Accident pilot training records showed that the mean number of years

[38] Between August 1, 2003, and April 30, 2004, the Safety Board investigated a total 1,129 GA accidents involving 1,144 aircraft. Of these, 226 were fatal accidents that resulted in a total of 381 deaths.

[39] Refer to appendix G for a list of the accidents included in this study.

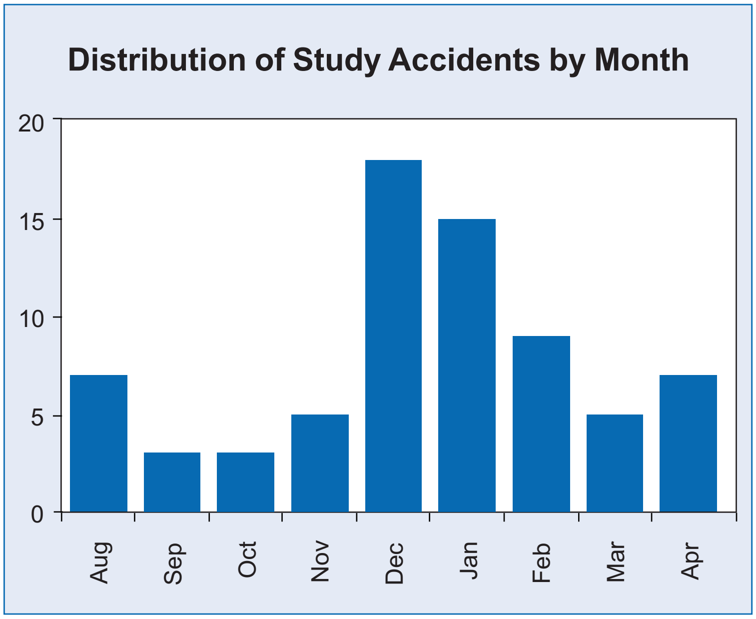

Figure 4

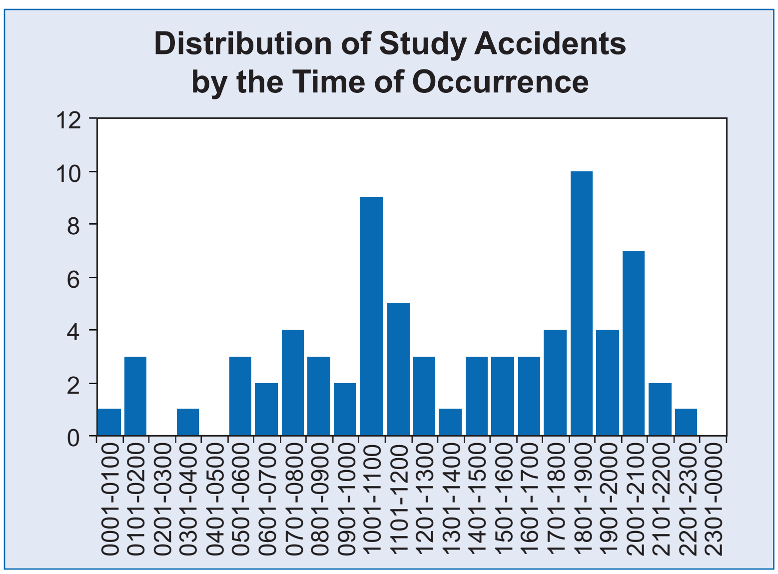

Figure 5

as pilot at the time of the accident was approximately 18 years and the mean age at which accident pilots received their first pilot certificate was 35 years. Of the 72 accident pilots, 4 percent held airline transport pilot certificates, 32 percent commercial pilot certificates, 61 percent private pilot certificates, and 3 percent student pilot certificates. As shown in figure 7, the distribution of study accident pilots by highest certificate was similar to the

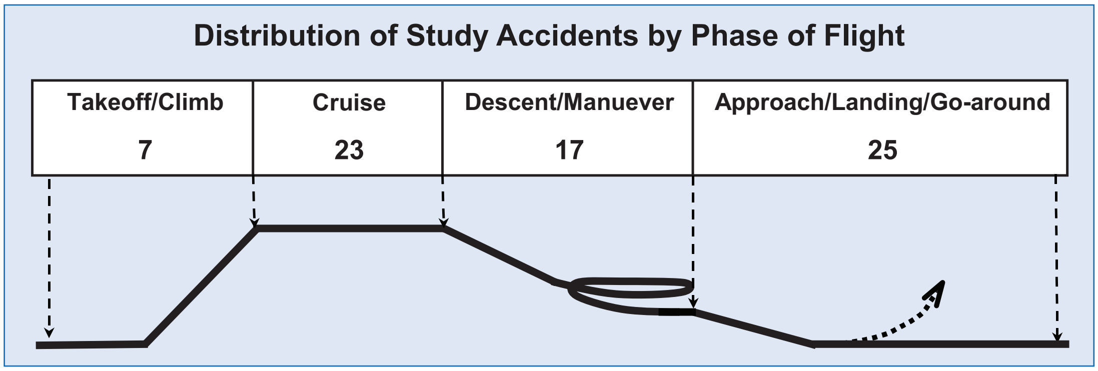

Figure 6

distribution of pilots involved in weather-related accidents from 1983 through 2001.[40] In comparison, 2003 FAA airman registry data[41] indicated that 23 percent of active pilots at that time held airline transport pilot certificates, 20 percent commercial pilot certificates, 39 percent private pilot certificates, and 14 percent student pilot certificates.[42] Approximately 68 percent of accident pilots were rated for instrument flight, compared to the 51 percent of the active pilot population who held an instrument rating.

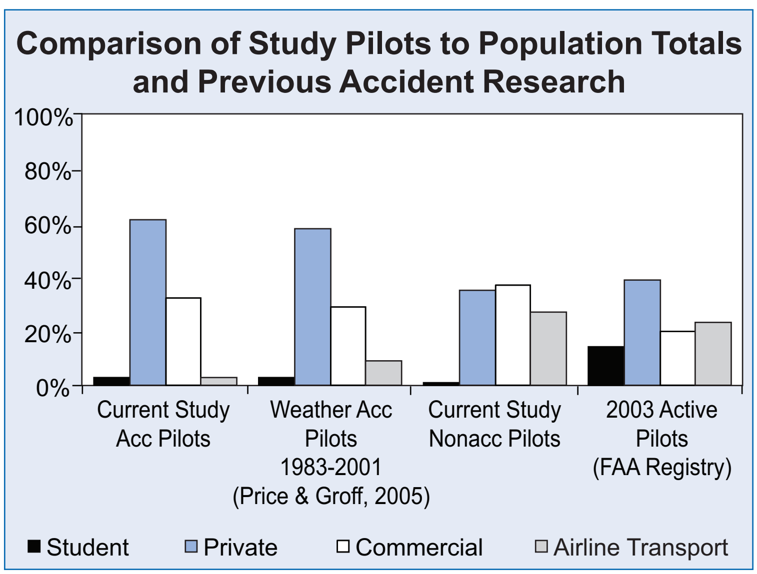

Figure 7

[40] Price and Groff (2005).

[41] U.S. Department of Transportation, Federal Aviation Administration, *U.S. Civil Airmen Statistics*, 2003, available online at <http://www.faa.gov/data_statistics/aviation_data_statistics/civil_airmen_statistics/>.

[42] The remainder includes recreational pilot, rotorcraft (only), and glider (only) certificates.

Nonaccident Pilots

Interviews were conducted with 135 pilots of matching nonaccident flights. Nonaccident study participants included 131 male and 4 female pilots, ranging in age from 19 to 74 years, with a mean age of 46 years. The mean number of years as a pilot was approximately 18 years for the nonaccident group, and the mean age at which nonaccident pilots received their first pilot certificate was 28 years.

Data pertaining to pilot age at the time of the flight, years as pilot, and age at first certificate were categorized in four groups[43] for analysis (figures 8, 9, and 10). The chi-square test indicated a significant difference between the accident and nonaccident groups with regard to age at the time of accident, $\chi^2 (3, N = 207) = 12.33, p < .01$.[44] Specifically, the nonaccident group included a higher percentage of pilots in the youngest (≤40) group, while the accident group included a higher percentage of pilots in the oldest (>60) group. However, there was no corresponding difference in the years of piloting experience between the accident and nonaccident groups, $\chi^2 (3, N = 207) = 1.52, p = .679$. The accident and nonaccident pilots did differ significantly by the age at which they first obtained their pilot certificates, $\chi^2 (3, N = 207) = 22.62, p < .001$. Figure 10 illustrates that a higher percentage of nonaccident pilots received their first pilot certificates before age 25, while the percentages represented in all other age groups were higher for accident pilots. .

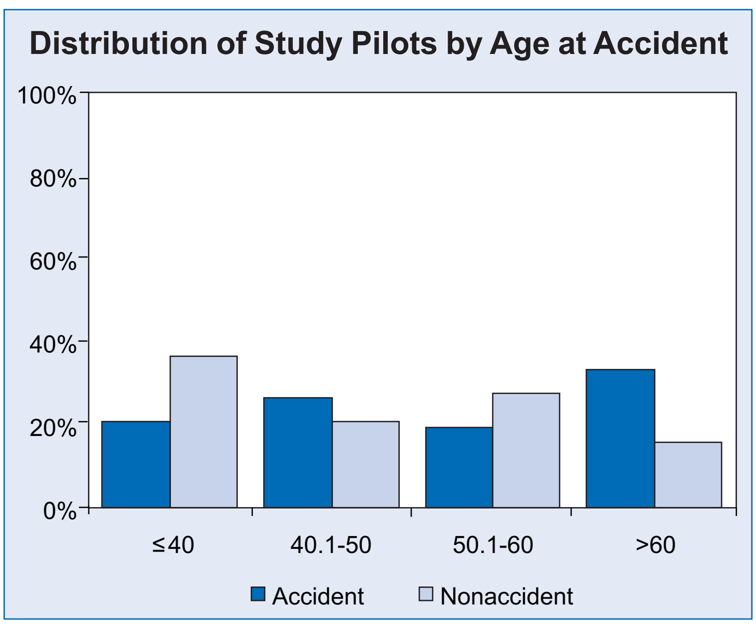

Figure 8

[43] Continuous variables were divided into discrete variables for analysis to simplify interpretation of results. Discrete variable categories were determined by dividing continuous values into quartiles. The resulting category cut-points were adjusted as necessary to create meaningful groups.

[44] In this study, results were considered statistically significant if the probability of the result being due to chance was less than 5 percent ($p < .05$).

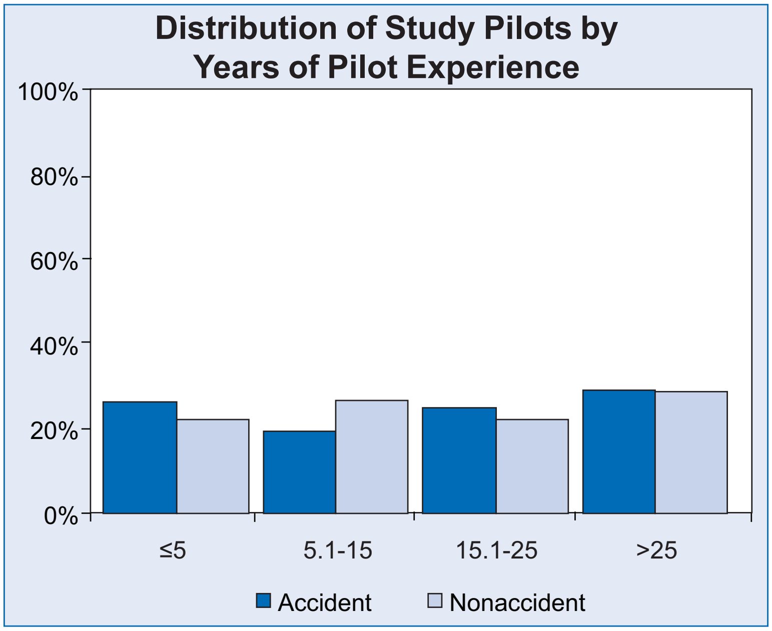

Figure 9

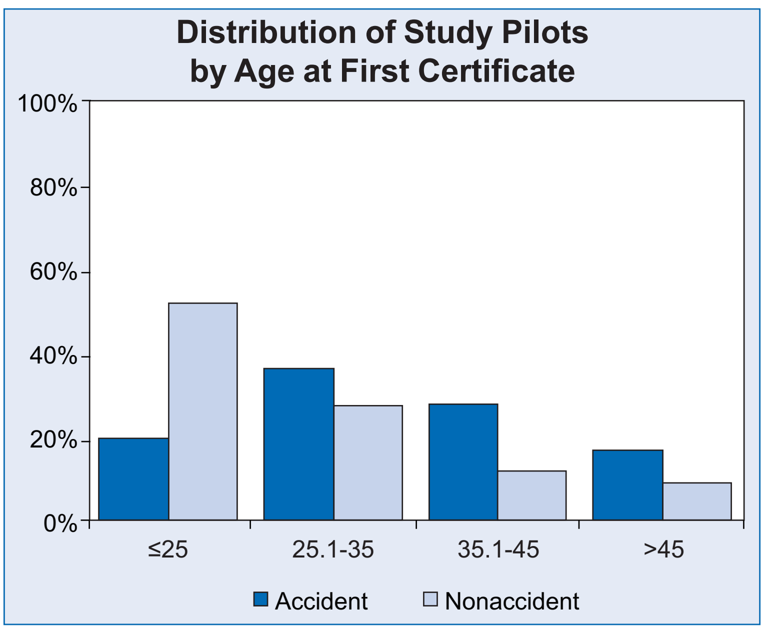

Figure 10

As shown in figure 7, 27 percent of the nonaccident pilots held airline transport pilot certificates, 37 percent commercial pilot certificates, 35 percent private pilot certificates, and 1 percent student pilot certificates. The chi-square analysis compared pilots with student or private pilot certificates to those with commercial or transport pilot certificates and found a significant difference between the accident and nonaccident groups, χ^2 (1, N = 207) = 15.21, p < .001, with a higher proportion of student and private pilots in the accident group. Additionally, about 90 percent of pilots in the nonaccident group held an instrument rating, compared to 68 percent of pilots in the accident group. The proportion of pilots with instrument ratings differed significantly for the accident and nonaccident groups, χ^2 (1, N = 207) = 16.28, p < .001.

Pilot Flight Hours

For most flight hour variables (for example, total time in aircraft make and model, actual instrument time, and time in the last 90 days), statistical comparisons could not be calculated because flight hour data for a large number of accident pilots were unavailable due to incomplete or missing pilot logs. The most commonly available information was that for total flight hours in all aircraft, partly because pilots are asked to report this information when renewing a medical certificate. Using this information, study managers were able to estimate total flight hours for accident pilots whose logbooks could not be recovered. The median total number of flight hours for the accident group (1,300 hours) was lower than the median total flight hours for the nonaccident group (2,270 hours). However, when pilots were divided into groups for analysis by total flight hours (shown in figure 11), the distributions were not found to be significantly different for the accident and nonaccident pilot groups, χ^2(3, N = 207) = 3.89, p = .274.

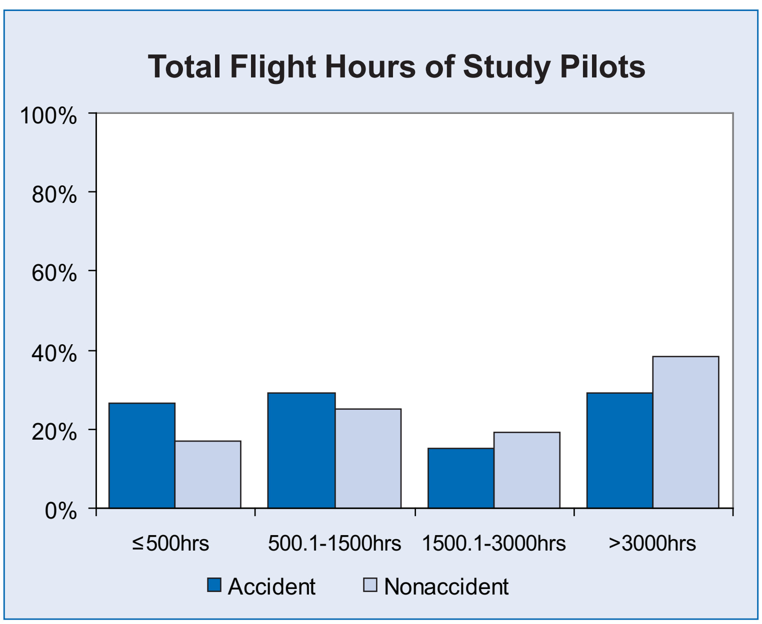

Figure 11

Pilot Testing History

Using test information for all accident and nonaccident pilots involved in the study, study managers calculated separate knowledge and practical test pass rates for each pilot using the results of his or her private, commercial, and instrument test(s). To allow them to compare the testing history of all study pilots regardless of the number of tests taken, study managers determined a "cumulative pass rate" by dividing the total number of written or practical tests passed by the total number of tests a pilot had taken. Knowledge and practical test records indicated that accident pilots had a mean cumulative pass rate of 86 percent for knowledge tests (max = 100 percent, min = 30 percent) and, for practical tests, a mean cumulative pass rate of 84 percent (max = 100 percent, min = 43 percent). Pilots in the nonaccident control group had a mean cumulative pass rate of 95 percent (max = 100 percent, min = 59 percent) for knowledge tests and, for practical tests, a mean cumulative pass rate of 95 percent (max = 100 percent, min = 50 percent).

Pilots were divided into two groups for the statistical analysis: a "high pass rate" group for all pilots with a cumulative pass rate of 70 percent or higher and a "low pass rate" group for those with a cumulative pass rate of less than 70 percent. As shown in figures 12 and 13, larger percentages of accident pilots were in the low pass rate group for both knowledge and practical tests. For the practical test, this difference between accident and nonaccident pilots was statistically significant, χ^2 (1, N = 207) = 4.42, p = .036, with 28 percent of accident pilots and 16 percent of nonaccident pilots falling into the low pass rate group. The difference in knowledge test pass rates between the groups was marginally significant, χ^2 (1, N = 207) = 3.75, p = .053.

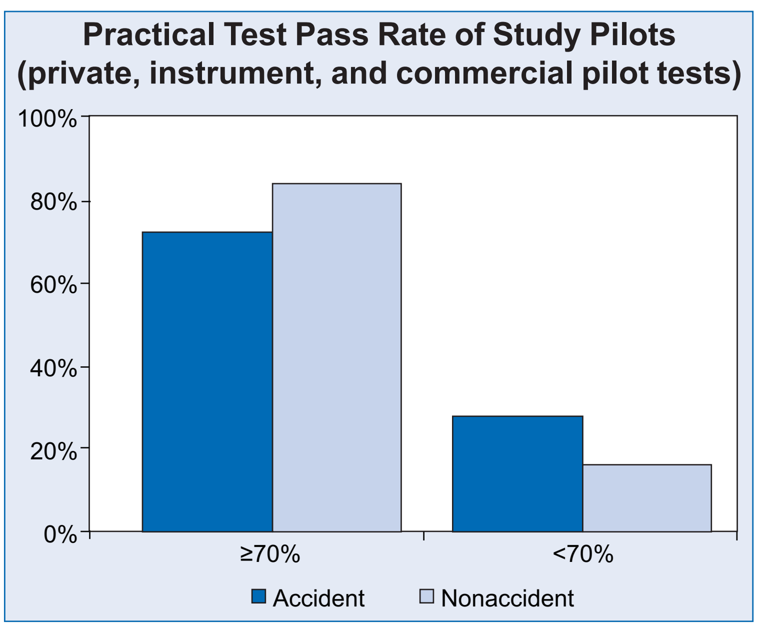

Figure 12

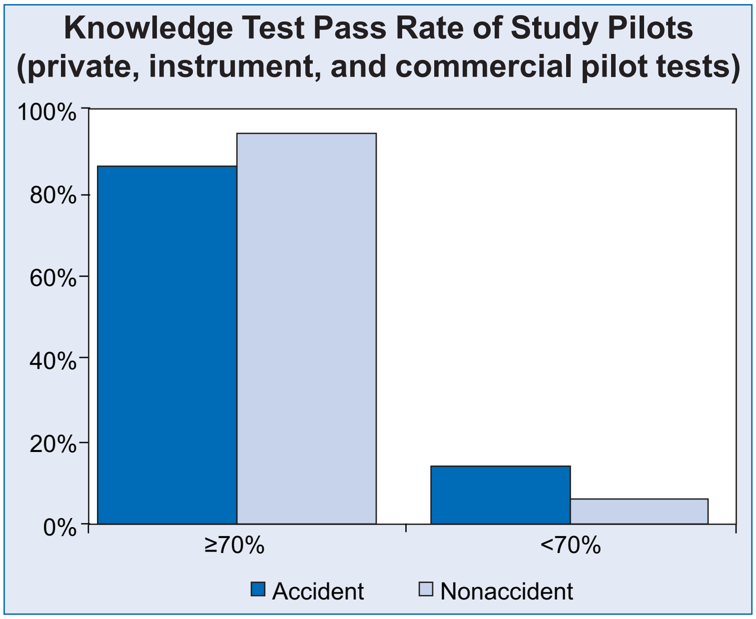

Figure 13

Accident, Incident, and Violation History

A review of the accident and incident history of study pilots indicated that 19 percent of accident pilots had an accident or incident before the study accident. In four of these cases, the event included in the study was the pilot's third recorded mishap. In contrast, figure 14 shows that a smaller proportion of pilots in the nonaccident control group were ever involved in an accident or incident. The differences in accident and incident history between groups was statistically significant, χ^2 (1, N = 207) = 3.99, p = .046, with a larger percentage of accident pilots having been involved in a prior occurrence.

In addition to accidents and incidents, FAA records indicated that 6 of the 72 study accident pilots had civil aviation violations on their records, in contrast to only 3 of the 135 nonaccident pilots. The descriptive comparison suggests that a higher percentage of accident pilots had violation records, but because of the small numbers of all study pilots with violations, statistical analyses were not conducted for these values.

Flight Information

Planned Length of Flights

The mean planned length of accident flights was 232 nautical miles, compared to a mean of 162 nautical miles for nonaccident flights. Study flights were separated into four groups according to the length of the planned flight (figure 15). Results of the chi-square analysis indicated a significant difference between the accident and nonaccident flights

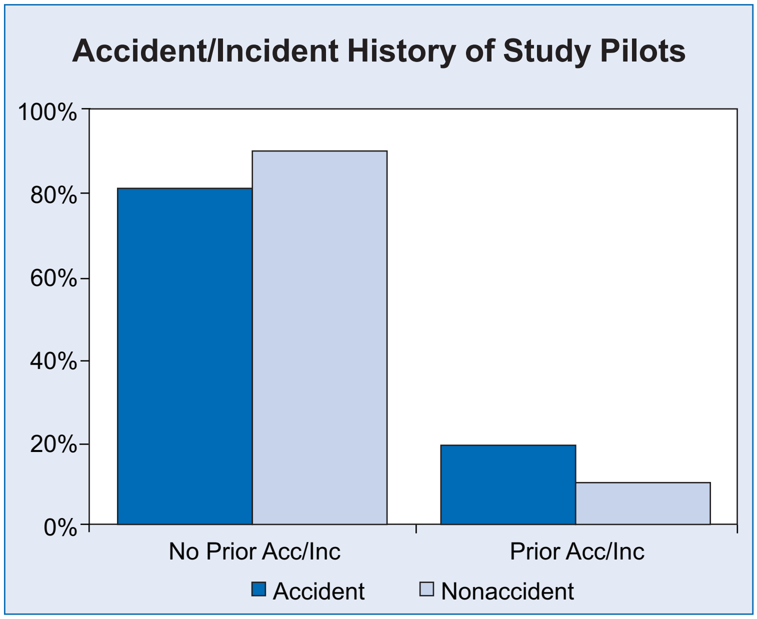

Figure 14

with regard to the intended length of flights, χ^2 (3, N = 207) = 8.25, p = .041. As figure 15 shows, the accident group included a higher percentage of planned flights in the longest group (>300nm), and the nonaccident group included a higher percentage of flights in the shortest planned length group (≤50nm).

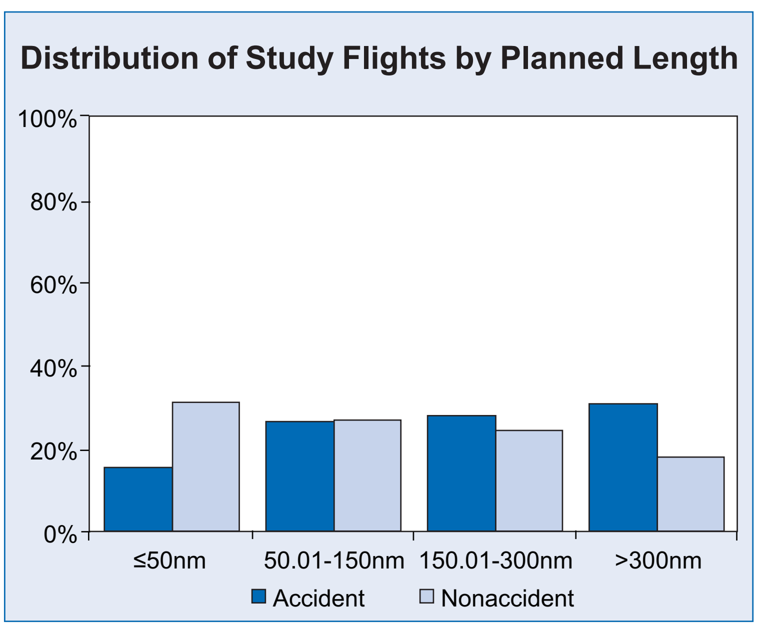

Figure 15

Purpose of Flight

As for the purpose of flight, the available information indicated that 17 percent of accident flights were being operated for pay, and the remaining 83 percent were unpaid operations. In contrast, 33 percent of the matching nonaccident flights were conducted for pay, and the remaining 67 percent were unpaid. Analysis results indicated a significant difference between the groups, χ^2 (1, N = 207) = 6.54, p = .011. The differences in proportion of paid flights are illustrated in figure 16.

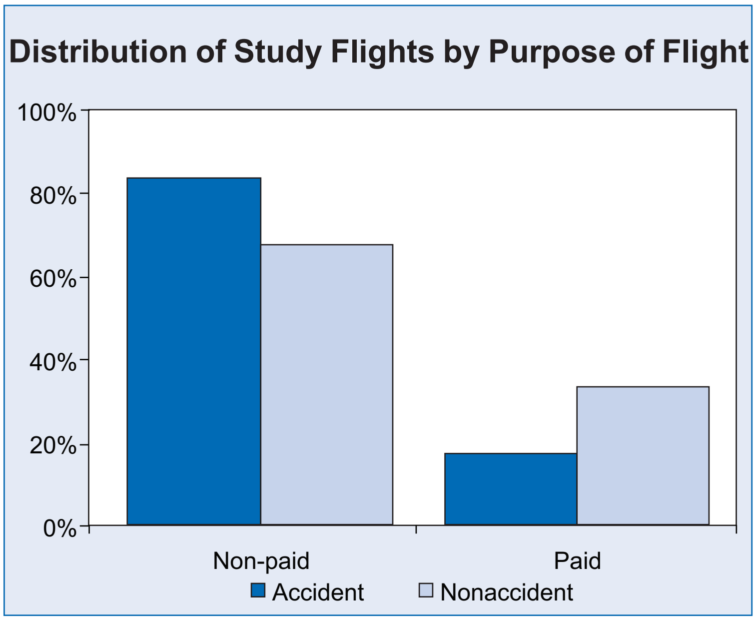

Figure 16

Aircraft Information

Aircraft Ownership

As shown in figure 17, 76 percent of the aircraft involved in study accidents were owned by the pilot either directly, through a limited liability corporation, or through shared ownership. About 10 percent of accident aircraft were rented, and the remaining 14 percent were owned by the pilot's employer or another entity. In comparison, 56 percent of the nonaccident aircraft were owned by the pilot, 13 percent were rented, and approximately 30 percent were owned by the pilot's employer or another entity.[45] Differences in aircraft ownership between the accident and nonaccident groups were statistically significant, χ^2 (2, N = 207) = 8.68, p = .013.

[45] Values do not sum to 100 percent due to rounding.

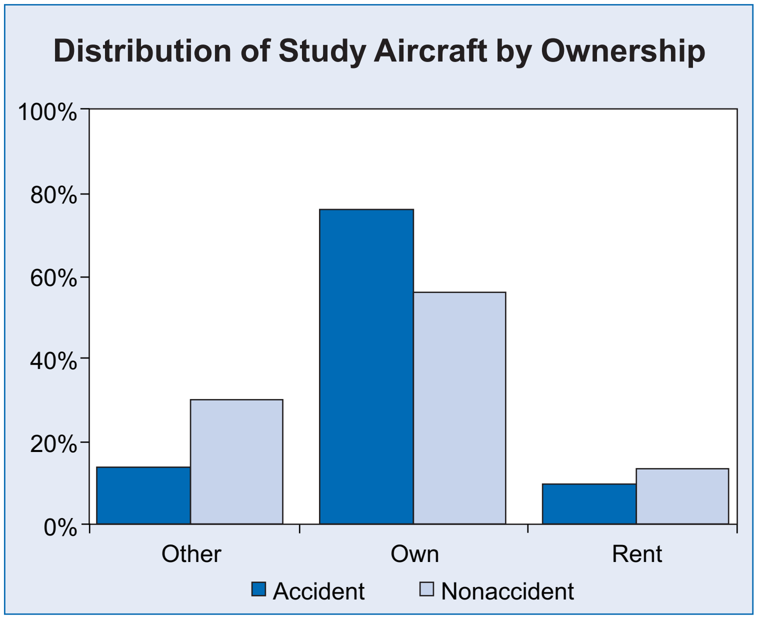

Figure 17

Aircraft Equipment

Pilot interviews, aircraft records, and examinations of accident aircraft wreckage were used in combination to collect information about the equipment on board accident and nonaccident aircraft. The equipment information available for accident aircraft was markedly less than for nonaccident aircraft. Fifteen of the accident aircraft in this study, or about 21 percent, sustained impact and/or post-crash fire damage so extensive that little or no information was available about aircraft avionics. For many of the accident aircraft, only partial equipment information was available from aircraft maintenance logs and repair and alteration records.[46] The extent of missing data for accident cases, and the lack of information about equipment use at the time of the accident, prevented study managers from making meaningful comparisons of accident and nonaccident aircraft equipment.

Summary of Chi-Square Analysis

Overall, the chi-square analysis identified several variables indicating significant differences between the accident and nonaccident groups: 1) age at accident, 2) age at first certificate, 3) highest certification, 4) instrument rating, 5) practical test cumulative pass rate, 6) accident/incident history, 7) planned length of flight, 8) purpose of flight, and 9) aircraft ownership.

Binary Logistic Regression Model

Following the individual comparisons, a binary logistic regression model was developed based on the results of the chi-square analyses and relationships hypothesized by

[46] As reported on FAA form 337, *Major Repair and Alteration.*

other researchers. The decision to include an individual variable in the logistic regression model was ultimately made based on the resulting effect on the ability of the model to predict accident/nonaccident status. In some cases, variables were included (for example, total flight time) because, although not statistically significant on their own, they added to the overall predictive capability of the regression model. In other cases, the strongest predictor was selected from two or more related variables (for example, age at private certificate instead of age at accident). Table 1 lists each of the variables included in the final binary logistic regression model, along with the results of the logistic regression analysis.

An overall test of the logistic regression model significance was calculated using a chi-square test of the model coefficients. The results of that test indicated that the model was statistically significant, χ^2 $(16, N = 207) = 57.45$, $p < .001$. The results of the logistic regression were also evaluated with regard to how accurately the model classifies accident and nonaccident flights. In this case, the logistic regression model resulted in an overall classification success rate of 77 percent (accurately identifying 121 of 135 nonaccidents and 38 of 72 accidents) compared to 65 percent without the model.

The significance of individual variables within the model was assessed using the Wald chi-square statistic, which tests the unique contribution of each variable. The Wald statistic is interpreted like the chi-square comparisons presented earlier. Of the variables entered into the model, planned length of flight, pilot age at first certificate, accident/incident history, and instrument rating were identified as unique and statistically significant predictors of accident involvement. Table 1 includes the Wald statistic and significance for all variables, and levels of variable, in the logistic regression.

For each predictor variable, the binary logistic regression analysis also produced odds ratios that reflected the relative accident risk associated with different levels of the variable. An odds ratio is interpreted as a comparison of the risk associated with each level of a variable with the selected reference. For example, if a variable has two levels (for example, yes and no), and the comparison of one level of the variable (for example, yes) to the level chosen as the reference (for example, no) results in an odds ratio of 2.0, the risk of involvement in a weather-related GA accident for a flight with that characteristic is twice as high as a flight that does not share that trait. The rightmost column of table 1 indicates the odds ratios associated with each level of variable.

Flight Leg Length

In comparison to a flight of 50 nautical miles (nm) or less, pilots on flights of 50.01 to 150 nm were 2.9 times more likely to be involved in a weather-related GA accident, and those on flights of more than 300 nm were 4.7 times more likely to be involved in a weather-related accident.

Table 1

Results of the Binary Logistic Regression Analysis (* indicates p < .05, ** indicates p < .01)		Total number of flights	Accident Flights	Wald	Sig.	Odds Ratio
Planned flight length				7.868	.049*	
	≦ 50.00	53	11	-	-	reference
	50.01 - 150.00	55	19	4.069	.044*	2.948
	150.01 - 300.00	53	20	3.066	.080	2.566
	>300.00	46	22	7.677	.006**	4.652
Pilot flight hours				1.057	.788	
	>3000.00	73	21	-	-	reference
	≦ 500.00	42	19	.149	.700	1.248
	500.01 - 1500.00	55	21	.108	.743	1.182
	1500.01 - 3000.00	37	11	.413	.520	.697
Age at first certificate				13.521	.004**	
	≦ 25.00	84	14	-	-	reference
	25.01 - 35.00	63	26	11.231	.001**	4.497
	35.01 - 45.00	36	20	8.879	.003**	4.814
	>45.00	24	12	3.950	.047*	3.434
Aircraft ownership				2.553	.279	
	Rent	25	7	-	-	reference
	Own	131	55	.453	.501	1.524
	Other	51	10	.936	.333	.443
Prior accident or incident						
	No	180	58	-	-	reference
	Yes	27	14	4.764	.029*	3.123
Highest pilot certificate						
	Commercial or higher	113	26	-	-	reference
	Private or less	94	46	.389	.533	1.353
Practical test pass rate						
	≧ 70%	166	52	-	-	reference
	< 70%	41	20	1.857	.173	1.788
Purpose of flight						
	Non-paid	150	60	-	-	reference
	Paid	57	12	2.055	.152	3.006
Instrument rating						
	Instrument rated	171	49	-	-	reference
	No instrument rating	36	23	9.546	.002**	4.767

Age at Private Certificate

Pilots with the lowest risk of accident involvement were those who received their private certificates at or before age 25. Pilots who received their private certificates between age 25 and 35 were found to be at 4.5 times greater risk than those in the youngest group of being involved in a weather-related accident, and those who received their certificates between 35 and 45 were at 4.8 times greater risk. Pilots who received their licenses after age 45 were 3.4 times more likely than the youngest group to be involved in a weather-related accident.

Prior Accident/Incident Involvement

Pilots with a history of any type of accident or incident were found to be 3.1 times more likely to be represented in the accident group than pilots with no such history.

Instrument Rating

Not having an instrument rating was associated with significantly higher accident risk. Specifically, pilots who did not hold an instrument rating were found to be 4.8 times more likely than instrument-rated pilots to be involved in a weather-related accident.

Chapter 6

Discussion

This study compared GA accident flights that occurred in reduced visibility conditions ("weather-related accidents") with a corresponding set of non-accident GA flights and identified several pilot- and flight-related factors that are associated with increased risk of accident involvement. This section focuses on several factors that distinguished accident from nonaccident pilots including their age, flight training, and performance history. It also discusses the sources of weather information used by all GA pilots in this study. The recommendations issued as a result of the study findings focus on three specific issue areas:

On January 19, 2004, about 0106 eastern standard time, a Piper PA-28-181, N298PA, impacted trees, a power line, and the ground while on an instrument landing system approach to the Saint Lucie County Airport, Fort Pierce, Florida. The certificated flight instructor and the private pilot-rated student were fatally injured, and a private-pilot rated passenger received serious injuries. Instrument meteorological conditions prevailed at the time and an instrument flight rules flight plan was filed for the 14 CFR Part 91 instructional flight (MIA04FA045).

1. Ensuring a minimum level of proficiency for all pilots to recognize and safely respond to hazardous weather situations.
2. Identifying and providing additional support for pilots whose performance history indicates an increased risk of weather-related accidents.
3. Providing GA pilots with additional guidance regarding sources of preflight weather information.

Age-Related Differences

The relationship between pilot age and accident risk has been the subject of research and debate, especially as it relates to the mandatory retirement age for Part 121 flight operations. Studies of age-related risk are subject to methodological choices and analytical issues that can substantially affect the resulting conclusions.[47] As a result, prior studies of age-related aviation risk have produced remarkably different findings, including a linear increase in risk with age,[48] a decreasing risk with age,[49] or no relationship between age and accident risk.[50]

The analysis in this study identified significant differences between accident pilots and nonaccident control group pilots with respect to age, but the groups were not found to be significantly different in experience as measured in years as a pilot or total flight hours. The combination of these results indicated that pilots in the nonaccident group started flying earlier in life, on average, than accident pilots. This finding was supported by the chi-square analysis finding that showed a significant difference between the accident and control groups with respect to age at certification, and the logistic regression analysis that identified pilot age at private certificate as a significant predictor of accident risk. Based on the results of these analyses, the Safety Board concludes that pilots who start flying earlier in life are at lower risk of being involved in a weather-related GA accident than those who start flying when they are older, and age at first certificate is a better predictor of future accident involvement than age at time of flight.

The changes in cognitive and physical functioning that occur with aging are well documented.[51] Conditions typically associated with age-related performance decrements, such as visual impairment or decreased mobility, are generally considered to begin about age 60, and an age-related increase in driving risk has been identified after age 75.[52] However, this study identified a significantly lower risk for pilots who began flying at age 25 or younger. Therefore, the Safety Board concludes that the observed connection between age and accident risk in this study is not likely due to physical aging issues, but to other factors associated with the age at which a person starts flight training.

---

[47] For a discussion of the specific methodological issues facing studies of age-related aviation risk, see the following: (a) D. Broach, *Methodological Issues in the Study of Airplane Accident Rates by Pilot Age: Effects of Accident and Pilot Inclusion Criteria and Analytic Strategy*, DOT/FAA/AM-04/8 (Washington, DC: FAA Office of Aerospace Medicine, 2004); and (b) G. Li, "Pilot-Related Factors in Aircraft Crashes: A Review of Epidemiologic Studies," *Aviation, Space, and Environmental Medicine*, 65 (1994): 979-85.

[48] D. Broach, *Methodological Issues in the Study of Airplane Accident Rates by Pilot Age: Effects of Accident and Pilot Inclusion Criteria and Analytic Strategy*, DOT/FAA/AM-04/8 (Washington, DC. FAA Office of Aerospace Medicine, 2004).

[49] E.J. Kay, D.J. Hillman, D.T. Hyland, R.S. Voros, R.M. Harris, and J.D. Deimler, *Age 60 Rule Research, Part III: Consolidated Data Base Experiments Final Report,* DOT/FAA/AM-94/22 (Washington, DC: FAA Office of Aerospace Medicine, 1994).

[50] G. Li, S.P. Baker, J.G. Grabowski, Y. Qiang, M.L. McCarthy, and G.W. Rebok, "Age, Flight Experience, and Risk of Crash Involvement in a Cohort of Professional Pilots," *American Journal of Epidemiology,* 157 (2003): 874-880.

[51] For reviews of aging literature, see the following: (a) A.D. Fisk and W.A. Rogers (eds.), *Handbook of Human Factors and the Older Adult* (San Diego, CA: Academic Press: 1997); (b) D.J. Hardy and R. Parasuraman, "Cognition and Flight Performance in Older Pilots," *Journal of Experimental Psychology: Applied* 3(4) (1997): 313-348; or (c) T.A. Salthouse, *Adult Cognition: An Experimental Psychology of Human Aging* (New York: Springer-Verlag, 1982).

[52] G.H. Li, E.R. Braver, and L.H. Chen, "Fragility Versus Excessive Crash Involvement as Determinants of High Death Rates per Vehicle-Mile of Travel Among Older Drivers," *Accident Analysis and Prevention,* 35(2) (2003): 227-235.

Although there may be several reasons for this finding, one of the likely differences between pilots who begin flying at different ages is their motivation for learning to fly and what they plan to do with their flying privileges. These factors can affect initial choices about the type of flight training pilots pursue and also have implications for the type of flying environment and oversight they will encounter over the long-term.

Many pilots who invest the time and money to learn to fly during their late teens or early twenties may do so with the intention of pursuing a career in aviation. In contrast, pilots who start flying in their thirties or later may be more likely to pursue flying for pleasure or personal transportation rather than as a potential career path. Support for this suggestion comes from this study's findings that nonaccident pilots had higher levels of certification, were more likely to be conducting paid flight operations, and were more likely to be flying an airplane belonging to someone else rather than their own airplane. The differences between pilots pursuing a career in aviation and those who fly for recreation or personal travel extend beyond flight hours and the equipment they operate, and those differences may explain the study findings.

Flight Training Differences

Many persons who start flight training with the intent of becoming paid professional pilots engage in full-time flight training that typically results in a regular schedule for practicing and testing knowledge and skills, regular oversight, and an immersion in the aviation environment. A typical professional pilot curriculum culminates with a commercial pilot certificate, multiengine rating, and either flight instructor or instrument flight instructor certificate. For these pilots, milestones like the private certificate or instrument rating are steps leading to the higher levels of experience and certification necessary for employment. Pilots who go on to find employment in aviation are subject to additional scrutiny and requirements from third parties such as their employers, the aircraft owners, their customers, and passengers.

Conversely, persons not training for a career in aviation may be more likely to train part-time with instructors at local airport FBOs or flight schools, and to have longer intervals between training sessions. Persons who pursue flying for recreation or personal travel may view the private pilot certificate or instrument rating as a final—not a first—step in flight training. Pilots who do not pursue higher levels of certification are expected to maintain and improve their skills and knowledge on their own through regular flight activity. Unlike the direct and indirect oversight of most paid flight operations, pilots engaging in personal or business flight operations are required to fly with instructors again only to satisfy the flight review requirement of 14 CFR 61.56.[53] Consequently, the safety of personal flight operations may be more dependent on the skill, ability, and judgment of individual pilots.

[53] Although nonregulatory, many aviation insurance companies stipulate additional recurrent training in order to maintain policies and/or favorable rates.

Periodic training is an important part of maintaining and increasing knowledge and skills, and this seems to be particularly true for weather-related information and flight operations. For example, a survey study of the general weather knowledge of GA pilots[54] found no differences related to total hours of experience or experience during the previous 6 months after correcting for the highest level of pilot training/certification. These findings prompted the study author to conclude the following:

> It appears that pilots generally require formal training to obtain weather knowledge and cannot be expected to acquire it on their own as they simply gain more flight experience.

To obtain any pilot certificate, applicants are required to demonstrate aeronautical knowledge and skills related to identifying hazardous weather, obtaining and interpreting weather information, and performing associated decision-making tasks. After initial certification, the only specific weather-related requirement applies to instrument-rated pilots, who must maintain a minimum level of flight activity in order to exercise the privileges of that rating. The results from this study and previous research suggest that flight activity alone may not be sufficient to enable pilots to maintain or improve their ability to avoid hazardous weather conditions. The Safety Board concludes that periodic training and evaluation may be necessary to ensure that pilots maintain weather-related knowledge and skills.

The Safety Board therefore recommends that the FAA add a specific requirement for all pilots who do not receive weather-related recurrent training, that the biennial flight review include the following: recognition of critical weather situations from the ground and in flight, procurement and use of aeronautical weather reports and forecasts, determination of fuel requirements, and planning for alternatives if the intended flight cannot be completed or delays are encountered.

In addition, pilots who were required to demonstrate a minimum level of proficiency in flight by reference to aircraft instruments for certification should maintain that minimum proficiency. Therefore, the Safety Board also recommends that the FAA should, for pilots holding a private, commercial, or airline transport pilot certificate in the airplane category who do not receive recurrent instrument training, add a specific requirement that the biennial flight review include a demonstration of control and maneuvering of an airplane solely by reference to instruments, including straight and level flight, constant airspeed climbs and descents, turns to a heading, and recovery from unusual flight attitudes.

---

[54] B. Burian, *General Aviation Pilot Weather Knowledge and Trainin*g, final report of the FAA, grant #00-G-020 (2002).

Testing, Accident, and Incident History

A history of mishaps and/or violations has been shown to be an indicator of an individual's future accident risk in both driving[55] and aviation,[56] and is a key component for the actuarial calculations used to set vehicle insurance rates and demerit-based law enforcement programs. Less is known about the relationship between airman test performance and aviation accident risk; however, a 2004 Safety Board accident investigation report suggested that multiple test failures are an indicator of poor pilot proficiency.[57]

Airman Knowledge and Practical Test Requirements

To obtain pilot certifications and ratings, airmen must pass knowledge and practical tests. Knowledge tests are designed to assess an applicant's understanding of the information that is necessary to exercise the privileges of a particular certificate or rating. Using a computerized testing system, the FAA administers over 100,000 knowledge tests each year at hundreds of testing centers. Three knowledge tests—the private pilot airplane, commercial airplane, and airplane instrument rating—account for almost half of all knowledge tests administered. Once airmen have passed a written test, received appropriate flight training, and obtained an instructor's endorsement, they are eligible to take the corresponding practical test. Practical tests, typically administered by FAA-designated pilot examiners, are designed to evaluate pilots' ability to apply their knowledge and skills in the actual flying environment.

As an example of FAA airman certification requirements, pilots who wish to add an instrument rating to their private or commercial certificates must pass both the instrument rating airplane knowledge test and the practical test. In 2004, the FAA administered 13,794 knowledge tests for the instrument airplane rating, and 93 percent of these tests received a passing score.[58] The test has 60 multiple-choice questions[59] representing multiple "knowledge areas," such as general aeronautical information, navigation using instruments, and aviation weather. The applicant must receive a score of 70 percent or higher to pass.

---

[55] L.S. Robertson and S.P. Baker, "Prior Violation Records of 1,447 Drivers Involved in Fatal Crashes, *Accident Analysis and Prevention,* 7 (1975), 121-128.

[56] (a) D.R. Hunter, "Retrospective and Prospective Validity of Aircraft Accident Risk Indicators," *Human Factors,* 43(4) (2001): 509-518; (b) G. Li and S.P. Baker, "Crash and Violation Experience of Pilots Involved in Prior Commuter and Air Taxi Crashes: A Historical Cohort Study," *Aviation, Space, and Environmental Medicine,* 66, 1131-35; and (c) G. Li and S.P. Baker, "Prior Crash and Violation Records of Pilots in Commuter and Air Taxi Crashes: A Case-Control Study," *Aviation, Space, and Environmental Medicine,* 65 (1994), 979-85.

[57] National Transportation Safety Board, *In-Flight Engine Failure and Subsequent Ditching, Air Sunshine, Inc., Flight 527, Cessna 402C, N314AB, About 7.35 Nautical Miles West-Northwest of Treasure Cay Airport, Treasure Cay, Great Abaco Island, Bahamas, July 13, 2003,* Aircraft Accident Report NTSB/AAR-04/03 (Washington, DC: NTSB, 2004).

[58] See <http://av-info.faa.gov/data/teststat/04volume.htm>. Pass rate data were not available for the private pilot instrument practical test.

[59] The 60 questions are selected from a test bank of over 700 questions.

FAA practical test standards for obtaining an airplane instrument rating require that pilot applicants be assessed on eight "areas of operation" that include topics such as preflight procedures, flight by reference to instruments, and emergency operations. Within those areas of operation, pilots must demonstrate proficiency by performing specific tasks, including an instrument cockpit check, basic instrument flight maneuvers, several instrument approach procedures, and emergency operations. In addition to demonstrating competency in each required task, applicants must successfully respond to an oral test, show overall proficiency, and exhibit good use of aeronautical decision-making.

Applicants who fail the knowledge or practical test receive a notice of disapproval that specifies the knowledge areas with incorrect answers or areas of operation in which tasks were not performed satisfactorily. According to 14 CFR 61.49, before re-taking a failed knowledge or practical test, applicants must receive additional training and endorsement from an authorized instructor stating that they are proficient to pass the test.

Test Performance and Accident Risk

In this study, pilots were grouped into high- and low-pass-rate groups depending on their past performance on knowledge and practical tests. Overall, higher percentages of accident pilots were represented in the low-pass-rate group for both the knowledge and the practical test. Results of the chi-square analyses indicated a significant difference between the accident and nonaccident groups, suggesting a relationship between test performance and subsequent accident involvement. Therefore, the Safety Board concludes that knowledge and practical test failures are both associated with a higher risk of a pilot being involved in a weather-related GA accident.

The Safety Board also notes that, unlike the practical test standards in which failure of one "area of operation" is grounds for failure of the entire test, no minimum number of questions must be answered correctly within a given "knowledge area" on the knowledge test. For example, an average of 12 out of 60 questions on the private pilot certification knowledge test are weather-related.[60] A pilot could answer all 12 questions incorrectly and still receive a score as high as 80 percent, which is well above the minimum passing score of 70 percent. The Safety Board concludes that a pilot can incorrectly answer all questions relating to weather on an airman knowledge test and still receive a passing score on the test.

The Safety Board believes that a basic understanding of aviation weather is an important prerequisite to obtaining any pilot certificate or rating. Therefore, the Safety Board recommends that the FAA establish a minimum number of weather-related questions that must be answered correctly in order to pass FAA airman knowledge tests. The establishment of such requirements will further ensure that pilots who pass a knowledge test will have demonstrated a basic understanding of aviation weather.

For pilots who repeatedly fail knowledge or practical tests, failure limits may be appropriate. The Safety Board suggested the potential need for such a limit during the

[60] According to the FAA Airman Testing Standards Branch, there are 10 versions of the private pilot airplane knowledge test, and the number of questions pertaining to weather range from 11 to 13.

investigation of a fatal accident on July 13, 2003, involving a Cessna 402C operated as an Air Sunshine commuter flight that ditched in the Atlantic Ocean following an in-flight engine failure.[61]

A review of FAA records revealed that over a 15-year period, the pilot involved in that accident had failed nine practical tests. Specifically, the pilot had failed two practical tests for his private pilot certificate, one practical test for his instrument pilot rating, one practical test for his airline transport pilot certificate, two practical tests for his flight instructor certificate, and three practical tests for his instrument instructor certificate.[62] The Safety Board concluded that "the pilot had a history of below-average proficiency before the accident flight, including numerous failed FAA flight tests, which contributed to his inability to maintain maximum flight performance and reach land after the right engine failed."

As a result of the Air Sunshine accident, the Safety Board recommended that the FAA:

> Conduct a study to determine whether the number of flight checks a pilot can fail should be limited and whether the existing system of providing additional training after a notice of disapproval is adequate for pilots who have failed multiple flight checks. On the basis of the findings of the study, establish a flight check failure limit and modify the recheck training requirements, if necessary. (A-05-02)[63]

The Air Sunshine accident is an example in which the pilot's poor test performance may have indicated an underlying skill or knowledge deficit. If failure limits or other measures had been in place when the Air Sunshine pilot undertook the certification process, he might have been identified for remedial training or prevented from flying.

Accidents and Incidents

During the same timeframe that data were being collected for the 72 accidents included in this study, the Safety Board investigated a total of 1,129 GA accidents, involving 1,144 pilots. In the 10 years from 1993 through 2002, an average of about 1 in every 330 active pilots in the United States was involved in a GA accident annually. A far greater number of pilots are involved in incidents each year that have less severe outcomes but represent similar lapses in safety. Typically, pilots involved in accidents and incidents are not seriously injured, and most continue to fly after being involved in these events.

---

[61] NTSB/AAR-04/03.

[62] Cumulative pass rate, 36 percent.

[63] Recommendation A-05-02 was issued on January 27, 2005, and its status is "Open—Await Response."

Pilot History of Accidents and Incidents

This study used FAA records to determine whether pilots with a history of accidents or incidents are at an increased risk of future weather-related accidents. Analysis of the accident and incident records for all study pilots showed significant differences between the accident and incident histories for the accident and nonaccident pilots. Not only were accident pilots significantly more likely to have had prior accidents and incidents, several accident pilots had been involved in more than one accident or incident before the study. Results of the logistic regression indicated that pilots involved in prior accidents or incidents were about 3 times more likely to be involved in a weather-related accident than pilots with no record of accidents or incidents. This finding is particularly interesting because the increased risk was not limited to prior accidents and incidents involving weather. Therefore, the Safety Board concludes that a history of accident or incident involvement is associated with a higher risk of being involved in a future weather-related GA accident.

Tracking a Pilot's Testing and Accident/Incident History

The results of this study demonstrate that both poor test performance and prior accident/incident involvement are linked to future accident involvement among GA pilots. Prior accident and incident involvement may indicate a pattern of risk and operating performance, whereas knowledge and practical testing performance may reflect an airman's overall training, knowledge, skills, and proficiency. These findings suggest a possibility for reducing accidents by identifying pilots at increased risk for weather-related accident involvement.

Currently, no formal requirements exist for tracking and reviewing GA pilot performance histories. However, a 1996 law established such a system for air carrier pilots after a series of Safety Board recommendations,[64] and ultimately the action of United States Congress, led to the *Pilot Records Improvement Act* (PRIA).[65] The intent of the PRIA was to make operators aware of the performance history of potential employees so that they could make appropriate hiring decisions about applicants who have exhibited a pattern of performance problems or regulatory violations. Pilots with a history of testing failures or violations are not restricted from engaging in flight operations by the PRIA, but they may be subject to more scrutiny by potential air carrier employers than applicants with better performance histories.

Once pilots are hired, the PRIA precludes employers from using pilots' preemployment records. However, as a means to identify pilots who may be at risk of accident involvement, certain companies have established oversight programs that allow them to identify and track pilots who have demonstrated performance deficiencies or failures in the training environment. The Safety Board highlighted the importance of such programs during its investigation of the December 18, 2003, accident involving Federal

[64] A-88-141 (Superseded), A-88-145 (Closed—Acceptable), A-89-004 (Closed—Acceptable), A-90-141 (Closed—Uunacceptable), A-90-144 (Closed—Acceptable), A-93-014 (Closed—Unacceptable).

[65] Section 502 of Public Law 104-26.

Express Flight 647,[66] and recommended that the FAA require all Part 121 air carrier operators to establish similar programs.[67]

Although there are currently no formal efforts to identify and track pilots with patterns of performance that indicate they are at increased risk of weather-related GA accidents, the results of this study suggest that it would be possible to use existing records to develop such a program. Because of the associations between testing performance, past accident and incident involvement, and future accidents, the Safety Board recommends that the FAA develop a means to identify pilots whose overall performance history indicates that they are at future risk of accident involvement, and develop a program to reduce risk for those pilots.

Pilot Weather Briefing Sources and Methods

In addition to the statistical analyses conducted as part of this study, the numerous nonaccident pilot interviews provided an opportunity to identify other weather-related safety issues. One of those issues was the use of preflight weather information. A common assumption is that pilots involved in weather-related accidents did not obtain adequate preflight weather forecast information for their route of flight and were therefore unaware of the weather conditions they encountered. In addition to attempting to determine if the pilot had obtained weather forecast information before the flight, study managers also tried to discover what sources the pilots used to obtain this information and the number of sources they consulted before their flights. The intent of collecting this information was to determine if the weather briefing activities of accident and nonaccident pilots varied systematically and if certain activities were more predictive of accident involvement.

Information about accident pilots' use of preflight weather was obtained by ASIs as part of their normal investigations. When pilots were fatally injured, investigators relied on documented briefings to determine if the pilots had obtained weather information before their flights. Although the FAA maintains records of FSS transactions, pilots' use of other weather information provided via television, Internet, or satellite sources is not typically documented. In 66 percent of the 72 study accidents, ASIs reported that the pilot had received preflight weather information. However, it is likely that some of the remaining 34 percent of accident pilots sought weather information that could not be identified after their accidents.

Weather briefing information for nonaccident pilots was gathered during their post-flight interviews, usually within 72 hours of a given flight, increasing the likelihood that the pilots' memories of their preflight activities were accurate. According to their reports, 94 percent of nonaccident pilots had checked at least one source for weather

---

[66] National Transportation Safety Board, *Hard Landing, Gear Collapse, Federal Express Flight 647, Boeing MD-10-10F, N364FA, Memphis, Tennessee, December 18, 2003,* NTSB/AAR-05/01 (Washington, DC: NTSB, 2005).

[67] Recommendation A-05-014 was issued on May 31, 2005, and its status is "Open—Await Response."

information before their flights, and 57 percent reported checking two or more sources. FSS was the most widely reported source of weather information, used by 58 percent of nonaccident pilots. Other sources, by order of use, were commercial satellite services such as WSI or Meteorologix[68] (28 percent), DUATS (25 percent), various Internet websites (21 percent), automated services like ATIS, ASOS, or AWOS (14 percent), and television (11 percent).

These data are consistent with survey research suggesting that pilots use a variety of sources and products to gather information about weather before a flight.[69] On the surface, the nonaccident pilots may appear to be more likely to gather preflight weather information. However, for the nonaccident pilots interviewed, 42 percent used only those sources that may not have left any record in the case of an accident. This proportion is even higher than the 34 percent of accident pilots for whom no weather briefing information was found. Knowing this, study managers concluded that current methods do not provide a means for determining if accident pilots are more or less likely than nonaccident pilots to seek weather information before a flight. Furthermore, because of the adverse weather conditions that were common to all flights in this study, both accident and nonaccident pilots may have been more motivated to check weather and to check multiple sources.

A majority of accident and nonaccident pilots in this study had contacted FSS before their flights, but most nonaccident pilots also reported checking other sources of weather information to supplement their FSS briefings. For example, many nonaccident pilots reported that they routinely use Internet and satellite services to obtain graphical depictions of current and forecast conditions. This information was consistent with previous surveys of GA pilots, which indicated that the pilots rely on a variety of weather sources including sources that are not part of a standard FSS briefing.

Pilots may choose to supplement the standard FSS briefing with weather information from alternative sources for a number of reasons. With the proliferation of websites and electronic sources that provide weather information, pilots can now easily access detailed weather images that can be printed for use in the cockpit; they can also access interactive tools that provide a more detailed representation of in-flight weather conditions than would be available through oral or textual briefings. The Safety Board concludes that GA pilots routinely consult alternative sources of aviation weather to obtain information that is not currently available from a standard weather briefing.

Part 91 regulations do not specifically require the use of any particular sources of weather information for GA pilots, but do require that all pilots familiarize themselves with weather and weather forecast information before beginning a flight. The instructions given to pilots about how to obtain a good preflight weather briefing in FAA Advisory

[68] WSI and Meteorologix are examples of commercial providers of weather products. Many airport FBOs provide GA pilots with data connections to such services.

[69] D. B. Beringer and R. Schvaneveldt, "Priorities of Weather Information in Various Phases of Flight," *Proceedings of the Human Factors and Ergonomics Society 46th Annual Meeting* (2002).

Circular AC00-45E, "Aviation Weather Service," are limited to FSS briefings and DUATS and do not provide guidance on how to evaluate or select other sources of weather information, and the FAA Aeronautical Information Manual identifies FSS and DUATS as primary weather sources. Because FSS and DUATS are currently the only sources of weather information endorsed by the FAA for use by GA pilots, it is important to ensure that the information and services provided by those sources meet the needs of the GA pilot community.

In February 2005, the FAA announced that it had selected a contractor to operate the agency's FSS system, which comprises 58 stations throughout the United States. At the time of this report, the contractor is expected to take over the FSS operations in late 2005. The Safety Board believes that the transition to new management for the FSS system is an opportune time for the FAA and its contractor to evaluate FSS methods for providing weather information. For example, the FAA should seek to understand why some pilots choose other sources over FSS briefings and to consider whether the FSS system would benefit from an updating and/or broadening of the services and products it provides. A better understanding of pilots' weather needs would allow the FAA and its contractor to improve the weather services and products they provide to pilots. The Safety Board therefore recommends that the FAA determine optimal information presentation methods and delivery systems for FSS weather information briefings, including the possibility of supplementing or replacing some portions of the current standard weather briefing with graphical data.

The results of study interviews suggest that many pilots use other sources to obtain weather data not included in a standard briefing and then contact FSS or DUATS to fulfill a perceived regulatory obligation. This creates the potential for pilot misinterpretation or confusion if weather information gathered from various sources appears to be more detailed than the FSS information. In some cases, the FAA and NWS contribute to this potential confusion by providing detailed graphical weather products with disclaimers indicating that the products are not suitable to meet the briefing requirement.[70]

Without specific guidance, some pilots may hesitate to consult electronic data sources or may use sources that are not adequate to meet the intent of 14 CFR Part 91.103. Therefore, the Safety Board recommends that the FAA revise guidance materials associated with pilot weather briefings to include guidance for pilots in the use of Internet, satellite, and other data sources for obtaining weather information suitable for meeting the intent of 14 CFR Part 91.103 and subsequently inform the aviation community about this change.

[70] For example, the "standard briefing" section of NWS/FAA site www.aviationweather.gov contains all of the information cited in AC00-45E as constituting a standard briefing, as well as additional graphical weather products, yet it includes a disclaimer stating that it should be "used for advisory purposes only."

Summary

This study used the case control methodology to determine factors associated with an increased risk of being involved in a weather-related GA accident. Within the context of this study, the identified factors resulted in a statistically significant model of weather-related accident risk. Although study analyses—and the recommendations that resulted from those analyses—were limited to the domain of weather-related GA accidents, it is possible that study findings would generalize to the larger population of GA operations.

Historic accident data suggest that reduced-visibility weather represents a particularly high risk to GA operations. However, rather than being unique, weather may simply test the limits of pilot knowledge, training, and skill to the point that underlying issues are identified. Additional research is necessary to determine whether the identified safety issues extend beyond weather, but it is likely that implementation of study recommendations will improve the safety of GA in general.

Findings

1. Pilots who start flying earlier in life are at lower risk of being involved in a weather-related general aviation accident than those who start flying when they are older, and age at first certificate is a better predictor of future accident involvement than age at time of flight.

2. The observed connection between age and accident risk in this study is not likely due to physical aging issues, but to other factors associated with the age at which a person starts flight training.

3. Periodic training and evaluation may be necessary to ensure that pilots maintain weather-related knowledge and skills.

4. Knowledge and practical test failures are both associated with a higher risk of a pilot being involved in a weather-related general aviation accident.

5. A pilot can incorrectly answer all questions relating to weather on an airman knowledge test and still receive a passing score on the test.

6. A history of accident or incident involvement is associated with a higher risk of being involved in a future weather-related general aviation accident.

7. General aviation pilots routinely consult alternative sources of aviation weather to obtain information that is not currently available from a standard weather briefing.

Recommendations

As a result of this safety study, the National Transportation Safety Board makes the following recommendations to the Federal Aviation Administration:

> Add a specific requirement for all pilots who do not receive weather-related recurrent training, that the biennial flight review include the following: recognition of critical weather situations from the ground and in flight, procurement and use of aeronautical weather reports and forecasts, determination of fuel requirements, and planning for alternatives if the intended flight cannot be completed or delays are encountered. (A-05-024)
>
> For pilots holding a private, commercial, or airline transport pilot certificate in the airplane category who do not receive recurrent instrument training, add a specific requirement that the biennial flight review include a demonstration of control and maneuvering of an airplane solely by reference to instruments, including straight and level flight, constant airspeed climbs and descents, turns to a heading, and recovery from unusual flight attitudes. (A-05-025)
>
> Establish a minimum number of weather-related questions that must be answered correctly in order to pass Federal Aviation Administration airman knowledge tests. (A-05-026)
>
> Develop a means to identify pilots whose overall performance history indicates that they are at future risk of accident involvement, and develop a program to reduce risk for those pilots. (A-05-027)
>
> Determine optimal information presentation methods and delivery systems for flight service station weather information briefings, including the possibility of supplementing or replacing some portions of the current standard weather briefing with graphical data. (A-05-028)
>
> Revise guidance materials associated with pilot weather briefings to include guidance for pilots in the use of Internet, satellite, and other data sources for obtaining weather information suitable for meeting the intent of 14 *Code of Federal Regulations* Part 91.103 and subsequently inform the aviation community about this change. (A-05-029)

Appendix A

Previous National Transportation Safety Board Safety Recommendations

A search of the Safety Board's Recommendations Database revealed that 82 recommendations on the safety of flight in IMC or visibility-related weather conditions have been issued since 1968. Recommendations have addressed a variety of topics, which may be grouped into three broad areas: 1) the collection and dissemination of weather information, 2) pilot training and operations, and 3) air traffic control issues.

Collection and Dissemination of Weather Information

A focus on the collection, measurement, presentation, and communication of weather information is apparent in the 82 recommendations the National Transportation Safety Board has made since 1968. Early recommendations called on the Federal Aviation Administration (FAA) to increase the number of weather observation sites and to develop or improve measurements of cloud heights, runway visual range (RVR), and slant visibility range. Other recommendations called for audio-recorded preflight weather information, a system for providing en route flight advisories, and data-linked information on precipitation and turbulence.

Although not all of the recommendations related to weather information were implemented at the time they were issued, most of the concerns raised in these recommendations have been addressed over the years by system-wide improvements in the way that weather information is gathered, presented, and disseminated. Pilots are now able to access an array of up-to-date meteorological information from the telephone, the Internet, and avionics that provide graphical weather information.

Pilot Training and Operations

Recommendations concerning the safety of flight in adverse weather have targeted both pilot training and flight operations. Initial training-related recommendations called for increased emphasis on aviation meteorology in pilot training. In the mid-1970s, the Safety Board recommended that the FAA—

1. increase the emphasis of meteorology and its applications in pilot training,
2. specify a minimum number of instructional hours dedicated to meteorological instruction,
3. require written examinations to assess a pilot's meteorological knowledge, and
4. require pilot license applicants to demonstrate their ability to procure and utilize weather information.

In response to these early recommendations, FAA increased its emphasis on the use of weather products and took action to encourage commercial pilots to obtain instrument ratings. However, the FAA did not set a minimum number of instructional hours dedicated to meteorological instruction, nor did it require any assessment of a pilot's knowledge or use of meteorological products. Since that time, the FAA has modified the curriculum for the private pilot certificate to include information on gathering and using weather information. The examination for the private pilot certificate also includes questions on these topics; however, due to the way the exam is scored, pilots who answer all of these questions incorrectly still may achieve a passing score.

The curriculum for the private pilot certificate also includes material on basic control of an aircraft by reference to instruments, and in 1997, the FAA began requiring a minimum 3 hours of instrument flight training as part of the experience requirements for a private pilot certificate. This instruction is intended to train pilots to recognize, avoid, and—if necessary—escape instrument meteorological conditions (IMC) if encountered. Additional instrument flight training is required for the commercial pilot license and for the instrument rating that allows pilots to fly in IMC.

Air Traffic Control

Recommendations directed to air traffic control (ATC) personnel have focused on informing pilots about changes in weather and providing assistance to pilots when visibility is limited. In response to Safety Board recommendations, FAA improved ATC distribution of center weather advisories (CWA) and hazardous inflight weather advisory service (HIWAS) information to pilots. The FAA also instituted procedures for tower supervisors to communicate deteriorating weather conditions to pilots via approach controllers. FAA has also developed training for controllers to assist VFR pilots who are caught in IMC. Finally, FAA has emphasized that controllers should adjust traffic flow to accommodate low altitude en route traffic when visibility is poor.

Table of Safety Recommendations

Please note that in table A1, the following abbreviations are used to denote the current status of the safety recommendations.

CAA: Closed—Acceptable Action

CAAA: Closed—Acceptable Alternate Action

CNLA: Closed—No Longer Applicable

CR: Closed—Reconsidered

CUA: Closed—Unacceptable Action

OAA: Open—Acceptable Response

OUA: Open—Unacceptable Response

Table A1. Previous NTSB Recommendations on the Safety of Flight in IMC or Visibility-Related Weather Conditions.

Rec. Number	Addressee	Year	Status	Status Date	Summary of Recommendation
A-02-8	FAA	2002	OAA		Revise any restrictions and prohibitions that currently reference or address "night" or "nighttime" flight operations in mountainous terrain so that those restrictions and prohibitions account for the entire period of insufficient ambient light conditions, and ensure that it is clear to flight crews when such restrictions and prohibitions apply.
A-01-35	FAA	2001	CR	07/16/2002	Amend FAA order 7110.65, "air traffic control," paragraph 10-2-5, "emergency situations," to include as emergencies (1) inadvertent entry into instrument meteorological conditions (IMC) by a visual flight rules aircraft and (2) in-flight failure of attitude instruments needed to operate safely in IMC if the affected aircraft cannot remain in visual meteorological conditions for the remainder of its flight.
A-01-36	FAA	2001	OAA		Develop and ensure that air traffic controllers receive academic and simulator training that teaches controllers to quickly recognize and aggressively respond to potential distress and emergency situations in which pilots may require air traffic control (ATC) assistance, including but not limited to (1) recognition of situations in which visual flight rules aircraft may be encountering instrument meteorological conditions; (2) an understanding of common aircraft system failures that may require ATC assistance or special handling; and (3) the application of specific techniques for assisting pilots that encounter such weather difficulties and aircraft system failures. Further, this training should be based on actual accidents or incidents, include a comprehensive review of successful flight assists and the techniques used, and be reviewed annually to ensure that the training materials remain current and effective.
A-01-58	FAA	2001	OAA		In cooperation with the National Weather Service, ensure that Center Weather Service Units are adequately staffed at all times when any significant weather is forecast.
A-01-71	NWS	2001	CAA	01/27/2003	In cooperation with the Federal Aviation Administration, ensure that Center Weather Service Units are adequately staffed at all times when any significant weather is forecast.
A-01-59	FAA	2001	OAA		Modify automated weather systems to accept runway visual range (RVR) data directly from RVR sensors.
A-01-56	FAA	2001	OUA		Incorporate, at all air traffic control facilities, a near-real-time color weather radar display that shows detailed precipitation intensities. This display could be incorporated by configuring existing and planned Terminal Doppler Weather Radar or Weather Systems Processor systems with this capability or by procuring, within 1 year, a commercial computer weather program currently available through the Internet or existing stand-alone computer hardware that displays the closest single-site Weather Surveillance Radar 1988 Doppler data or regional mosaic images.
A-01-72	NWS	2001	OAA		Eliminate the Automated Surface Observing System lockout feature as soon as possible.
A-97-27	FAA	1997	CAAA	01/14/1999	Require, under the Standard Terminal Automation Replacement System (STARS) Program, that minimum safe altitude warning (MSAW) alerts on instrument flight rules (IFR) aircraft be duplicated at a position in the operational quarters designated for supervisory personnel and that the supervisor determine the validity of the alert and whether appropriate corrective action has been initiated or is required.
A-96-049	FAA	1996	CUA	07/08/1998	Require that hazardous in-flight weather advisory service (HIWAS) broadcasts consistently include all pertinent info contained in weather reports & forecasts, including in-flight weather advisories, airman's meteorological info (AIRMETs), significant meteorological info (SIGMETs), & center weather advisories (CWAs).

A-96-050	FAA	1996	CAA	08/20/1997	Encourage principal operations inspectors (POIs) & operators to reemphasize to pilots that hazardous in-flight weather advisory service (HIWAS) is a source of timely weather info & should be used whenever they are operating in or near areas of potentially hazardous weather conditions.
A-95-41	FAA	1995	CAA	06/09/1997	Amend FAA order 7110.65, Air Traffic Control, Chapter 2, General Control, section 6, weather information, paragraph 2-115, reporting weather conditions, to require the tower supervisor to notify tower & radar approach control facility personnel, in addition to the National Weather Service observer, of the deterioration of prevailing visibility to less than 3 miles. Additional, require the controllers to issue the visibility value to pilots until the info is broadcast on the ATIS & the pilots have acknowledged receipt of the information.
A-89-112	FAA	1989	CAA	05/04/1992	Provide radar control trainees in the en route option at the radar training facility an emergency situation in which a VFR pilot is asking for assistance, is caught in weather, but is below the minimum IFR altitude.
A-89-113	FAA	1989	CAA	05/04/1992	Provide radar control trainees in the terminal option at the radar training facility an emergency situation in which a VFR pilot is asking for assistance, is caught in weather, but is below the minimum vectoring altitude.
A-88-20	FAA	1988	CUA	01/10/1989	Amend chapter 2, section 6, paragraph 2-101, of the air traffic control handbook, 7110.65e, to require air traffic controllers to frequently broadcast the significant hazardous weather reports that are in effect.
A-88-21	FAA	1988	CAA	06/21/1989	Amend chapter 4, section 7, paragraph 343, subparagraph (1)(h) of the airman's information manual to include airborne weather radar as an item of equipment whose complete or partial loss of capability should be reported to air traffic control.
A-88-22	FAA	1988	CAA	06/21/1989	Amend chapter 2, paragraph 2-7 of the air traffic control handbook, 7110.65e, to include airborne weather radar equipment as an in-flight equipment loss or malfunction covered by this paragraph.
A-88-23	FAA	1988	CAAA	08/16/1991	Expedite the implementation of the hazardous in-flight weather advisory service program in all air route traffic control centers within the conterminous united states, before the summer convective weather season of 1988.
A-86-68	FAA	1986	CUA	10/07/1987	Include a message on the automatic terminal information service broadcast whenever weather conditions conducive to thunderstorm or microburst development exist in the terminal area or when such actual conditions have been observed or reported.
A-86-69	FAA	1986	CAA	07/28/1987	Amend Federal Aviation Handbook 7210.3g, Facility Operation and Administration, to require the observation of lightning or existence of cumulonimbus and towering cumulus clouds as items to be included on Automatic Terminal Information Service broadcast when that information has been included in the remarks section of official weather reports.
A-86-71	FAA	1986	CUA	10/27/1988	Develop a position in major terminal facilities, to be staffed with national weather service meteorologists or Federal Aviation Administration personnel trained for meteorological observations, to be the focal point for weather information coordination during periods of convective weather activity that adversely affects aircraft and air traffic control system operations.
A-86-74	FAA	1986	CAA	12/16/1986	Issue a general notice to all en route and terminal facilities emphasizing the phraseology requirements for describing weather areas as stated in Federal Aviation Administration Handbook 7110.65d.
A-86-76	FAA/NWS	1986	CUA/ CAAA	10/13/1987, 2/22/1994	Develop procedures to require that center weather service units are attended constantly during operation so that information concerning hazardous weather conditions, such as thunderstorms, wind shear, icing, and turbulence, either occurring or expected to occur, receives prompt, appropriate dissemination.

A-86-77	FAA/NWS	1986	CUA	10/13/1987, 07/22/1988	Develop procedures to require the center weather service unit meteorologist to disseminate information on rapidly developing hazardous weather conditions, such as thunderstorms and low-altitude windshear, to Federal Aviation Administration terminal radar approach control and/or tower facilities immediately upon detection of the conditions.
A-86-78	FAA/NWS	1986	CAA	07/04/1991, 07/22/1988	Expedite the implementation of equipment to upgrade all center weather service units to the state of the technology in data acquisition and display capability.
A-86-80	NOAA	1986	CAA	07/22/1988	Require that all offices that have a weather radar display or displays and an aviation weather warning responsibility to airports have those airports clearly located on a usable map on each weather radar display.
A-86-81	NOAA	1986	CUA	04/15/1998	Develop definitive aviation weather warning criteria based on radar weather echo intensities and the proximities of radar weather echos to airport approach and departure corridors, and implement a means to communicate this information immediately to Federal Aviation Administration terminal radar approach control and tower facilities.
A-84-111	FAA	1984	CAA	01/17/1986	Postpone nationwide implementation of the hazardous inflight weather advisory service program at air traffic control centers until the broadcasting procedures are improved and program information is disseminated widely.
A-84-112	FAA	1984	CUA	01/17/1986	Designate communication frequencies within the 118-135 mhz band for each air route traffic control center to broadcast hazardous inflight weather advisory service information.
A-84-113	FAA	1984	CUA	01/17/1986	Develop procedures similar to those currently used in terminal areas for automatic terminal information service, for flight crews to monitor an individual facility's hazardous inflight weather advisory service frequency and to inform the controller/facility on initial contact that the flight has the current HIWAS information.
A-84-114	FAA	1984	CAA	01/17/1986	During a transition period following the further implementation of hazardous inflight weather advisory service, require air traffic controllers to advise flight crews when critical safety information is being made available through HIWAS. For example, ARTCC controllers should be required to advise flights upon initial contact "significant weather information available on HIWAS."
A-83-17	FAA	1983	CAA	04/02/1985	Require that automatic terminal information service advisories be amended promptly to provide current wind shear information and other information pertinent to hazardous meteorological conditions in the terminal area as provided by center weather service unit meteorologists, and that all aircraft operating in the terminal area be advised by blind broadcast when a new automatic terminal information service advisory has been issued.
A-83-18	FAA	1983	CAAA	01/23/1996	Evaluate methods and procedures for the use of current weather information from sources such as radar, low level wind shear alert systems, and pilot reports as criteria for delaying approach and departure operations which would expose the flight to low altitude penetration of severe convective weather.
A-82-045	NWS	1982	CAA	10/05/1982	Establish a policy of transmitting all nonscheduled airport terminal forecasts and amendments to the Federal Aviation Administration weather message switching center in Kansas City, Missouri, for distribution on service a circuits.
A-82-17	FAA	1982	CAA	07/15/1982	Issue an emergency airworthiness directive specifying the installation of the dual vacuum pump accessory kit in all Cessna model 210n aircraft equipped with deicer boots as a requirement for flight into known instrument meteorological conditions.

A-82-30	FAA	1982	CUA	01/07/1983	Take action to amend 14 CFR 91.116 to provide that takeoffs cannot be initiated or an approach continued past the final approach fix or into the final approach segment of an instrument approach procedure unless the latest weather report for that airport issued by the U.S. National Weather Service, a source approved by that service, or a source approved by the administrator, reports the visibility to be equal to or more than the visibility minimums prescribed for that procedure.
A-81-162	FAA	1981	CAA	01/28/1985	Require all holders of an instrument rating and a multiengine rating to demonstrate their ability to operate a multiengine aircraft under normal and emergency conditions by reference to flight instruments only as a prerequisite to exercising the privileges of an instrument rating in multiengine aircraft.
A-81-23	FAA	1981	CAA	05/24/1984	Publish procedures in air traffic control handbook 7110.65b covering the control handling of center weather advisories.
A-81-8	FAA	1981	CAA	01/06/1984	Develop and implement a priority message-handling procedure to assure the immediate delivery of urgent weather messages to all weather circuits that originate from the weather message switching center in Kansas City, Missouri.
A-81-94	FAA	1981	CAA	12/10/1981	Audio-record all weather briefings provided by FSS personnel and retain such records for a reasonable period of time.
A-81-95	FAA	1981	CAA	12/10/1981	Take steps to ensure that all FSS personnel who provide weather briefings comply with the weather briefing procedures published in flight services handbook 7110.10.
A-80-115	FAA	1980	CAA	06/19/1985	Expedite the delivery of NWS weather radar color remote displays to all air route traffic control centers' center weather service units.
A-80-117	FAA	1980	CAA	10/15/1984	Expedite the development of appropriate graphic mapping techniques for correlation of the NWS weather radar color remote display and the air traffic controller's radar display presentation.
A-80-118	FAA	1980	CAA	07/02/1993	Expedite the development of an integrated weather radar/air traffic control radar single video display system capable of providing multiple weather echo intensity discrimination without derogation of air traffic control radar intelligence.
A-80-119	FAA	1980	CAA	06/19/1985	Require air route traffic control centers to make maximum use of the existing national weather service radar sites as inputs to the color remote displays at their facilities.
A-80-135	FAA	1980	CAA	05/24/1982	Require that flow controllers and supervisory personnel assess the potential effects of hazardous weather on low-altitude en route traffic and use the evaluation to adjust air traffic flow as necessary.
A-80-136	FAA	1980	CAA	06/08/1982	Require that the effect of precipitation-induced attenuation on x-band airborne weather radar be incorporated into airline training programs and that airborne weather radar manufacturers include attenuation data in radar operators handbooks.
A-80-109	FAA	1980	CUA	07/23/1986	Require that the effect of precipitation-induced attenuation on x-band airborne weather radar be incorporated into airline training programs and that airborne weather radar manufacturers include attenuation data in radar operators handbooks.

A-79-055	FAA	1979	CAA	10/29/1979	Revise air traffic control handbook 7110.65a so that a VFR aircraft issued an altitude assignment or instruction is provided terrain protection comparable to that received by an IFR aircraft. However, sufficient latitude should be provided in the handbook so that the controller may approve a request of a pilot who wishes to exercise the provisions of the exceptions to 14 CFR 91.79.
A-78-34	FAA	1978	CUA	10/26/1988	Install an alerting feature on all existing and new equipment for disseminating essential weather information in all air traffic control facilities, at positions that require timely information and at positions that are required to issue current weather information as a part of their air traffic control functions.
A-77-63	FAA	1977	CAA	06/18/1990	Expedite the development and implementation of an aviation weather subsystem for both en route and terminal area environments, which is capable of providing a real-time display of either precipitation or turbulence, or both and which includes a multiple-intensity classification scheme. Transmit this information to pilots either via the controller as a safety advisory or via an electronic data link.
A-77-65	FAA	1977	CAAA	08/15/1978	Transmit SIGMETs more frequently on NAVAIDs so that pilots can receive more timely information about hazardous weather.
A-77-66	FAA	1977	CAA	08/15/1978	Code, according to geographic applicability, severe thunderstorm watch bulletins and tornado watch bulletins issued by the national severe storms forecast center so that they may be transmitted to appropriate air traffic control facilities by the FAA weather message switching center; thus, air traffic control facilities can relay the earliest warning of severe weather to flight crews.
A-76-123	FAA	1976	CR	05/22/1980	Institute procedures which require air traffic controllers to release an aircraft from all airspeed restrictions at least 3 to 4 miles outside of the outer marker on all ILS approaches when the reported weather is below basic VFR minimums.
A-76-29	FAA	1976	CAAA	04/07/1977	Amend that portion of 14 CFR 91.33 applicable to instrument flight rules to require a source of energy for the rate-of-turn indicator separate from that used to power the bank and pitch indicator.
A-75-70	FAA	1975	CAA	12/22/1978	Change the wording of the restriction on the national ocean survey instrument approach charts for locations where night approaches are not authorized so that the restriction is clearly understood.
A-75-71	FAA	1975	CAAA	01/27/1977	Advise pilots arriving in a terminal area on an IFR flight plan whenever the published instrument approach procedure is not authorized for night operations. Instead of an approach clearance, issue a clearance to cruise at the appropriate minimum en route altitude/minimum obstruction clearance altitude (MEA/MOCA) at night.
A-74-19	FAA	1974	CAA	09/14/1978	Issue an advisory circular which describes the RVR equipment and emphasizes that the RVR value is a sampling of a small segment of the atmosphere, usually near the touchdown point. it should also be emphasized that RVR value does not necessarily represent actual runway visibility conditions near the touchdown point and includes a significant time delay before reaching the crew. This information should also be placed in the airman’s information manual.
A-74-127	FAA	1974	CR	10/01/1975	Amend 14 CFR 91.105 to require the same weather minimums outside controlled airspace as are required within controlled airspace.
A-74-14	FAA	1974	CAA	05/24/1984	Implement, in cooperation with the national weather service, a system to relay severe thunderstorm and tornado warning bulletins expeditiously to inbound and outbound flights when such bulletins include the terminal area.

A-74-30	FAA	1974	CUA	01/11/1979	Install conventional transmissometers or other visibility measuring devices in the approach areas of instrument runways.
A-74-32	FAA	1974	CUA	01/11/1979	Combine the approach zone transmissometer or visibility readings with the ceilometer readings to produce estimates of "threshold contact height."
A-74-33	FAA	1974	CUA	01/11/1979	Employ runway observers to take cloud height and visibility observations in the approach area whenever the prevailing visibility becomes 1 mile or less at those locations having minimums of less than 1 mile. These observers should be used until the instruments described in 1. Above are installed in the approach area.
A-74-67	FAA	1974	CAA	12/03/1975	Amend 14 CFR 141 to increase the required minimum of 35 hours of classroom instruction given to private pilot trainees, and specify the number of hours of meteorological instruction required.
A-74-68	FAA	1974	CUA	12/03/1975	Require that written meteorology examinations be designed to measure an applicant's knowledge of the practical application in addition to technical aspects of meteorology.
A-74-69	FAA	1974	CAAA	03/10/1977	Amend 14 CFR 61.57(b) to require a demonstration of the applicant's competence to procure and utilize weather information which will enable him to exercise safely the privileges of his pilot's certificate.
A-74-70	FAA	1974	CR	10/01/1975	Amend 14 CFR 61.125 aeronautical knowledge (a) airplanes, to require an applicant for a commercial pilot certificate to present evidence of meteorological knowledge in addition to the other areas of aeronautical knowledge now specified, similar to the requirements of 14 CFR 61.125 (b)(2), (c)(3), (d)(5), or (e)(3).
A-74-71	FAA	1974	CAA	06/04/1975	Increase the emphasis on aviation meteorology and weather limitations of pilots through its general aviation accident prevention program.
A-74-72	FAA	1974	CAA	06/04/1975	Take priority action in order to adhere to the proposed 4-year implementation plan for the en route flight advisory service (Flightwatch) program.
A-74-73	FAA	1974	CAA	12/03/1975	Implement, at least on an experimental basis at selected high general aviation activity locations, the audio recording of preflight weather briefings.
A-74-74	NOAA	1974	CAA	12/03/1975	Accelerate efforts to update, publish, advertise, and disseminate the document entitled Aviation Weather for Pilots and Operations Personnel.
A-74-75	NOAA	1974	CAA	02/20/1975	Accelerate the expansion of the evaluation staff to its proposed complement of one evaluations meteorologist per state and include in his responsibilities the implementation of a quality control program for aviation weather observations.
A-74-76	NOAA	1974	CNLA	02/20/1975	Accelerate efforts to improve the presentation of aviation weather products.
A-72-105	FAA	1972	CAA	01/01/1975	Visibility and separation from cloud distances should be assessed conservatively in VFR operations, and that VFR flight should be continued only when visibility is unquestionable.
A-72-139	FAA	1972	CUA	12/03/1975	Combined efforts and resources of government and industry be applied toward the expeditious application and use of technological advances in the field of all weather flight navigation and approach/landing systems. Although it cannot be stated unequivocally that this accident would not have occurred if an instrument landing system or more advanced landing system had been in use, it is the board's belief that the probability of the occurrence of such an accident would have been greatly reduced.

A-72-198	FAA	1972	CAA	11/30/1973	The FAA ensure widespread dissemination of information to pilots in all segments of aviation regarding the potential hazards associated with weather conditions characterized by a partial obscuration of the sky caused by a shallow layer of dense fog.
A-72-43	FAA	1972	CUA	06/08/1972	Issue an advisory circular incorporating excerpts of this report, including the findings, stressing to all instrument and airline transport pilots the need for continuous surveillance of flight instruments when operating in instrument meteorological conditions.
A-70-63	10 airlines and private flying organizatio ns	1970	CNLA	03/22/1971	The Board's review of these and other approach and landing accidents show that they occur with needless regularity and that they are not confined to a single segment of aviation. It was emphasized that there were a number of factors which must be considered in preventing this type of accident, namely, airborne and ground equipment, procedures and piloting techniques and judgment. Safety should be in continually improving the quality and increasing the quantity of landing aids and weather reporting facilities and services. it was further emphasized that all pilots should be thoroughly instructed in the hazards associated with shallow fog penetration and be prepared to make the missed approach decision and execute it without delay whenever the alternative course is required. Illusions tending to disorientate the pilot during the final phases of the approach and the limitations of various systems are but two of the areas bearing upon such a decision which must be recognized.
A-69-1	FAA	1969	CAA	02/17/1969	1. Amend sections 91.117 and 121.649 of the federal aviation regulations "to prohibit any approach below 200 feet above field level unless the pilot has the runway threshold in sight and require that he continue to have same in sight during the remainder of the approach." 2. "Bring to the attention of all instrument pilots the hazards associated with shallow fog penetration." 3. Include as mandatory items in airline training programs and FAA-approved instrument flight school curriculums "information on shallow fog penetration, the effect upon the guidance segment, and the potential illusions that can be created." 4. "Pursue as expeditiously as possible" its research into instrumentation which would provide slant visual range information. 5. set standards and specifications and encourage the development of "realistic" low-visibility-approach flight simulators. 6. program improved approach zone lighting covering "at least the last 1,000 feet of the approach" for "installation on a priority basis," when and if "financial conditions permit," at airports prone to frequent heavy fog.
A-69-32	FAA	1969	CUA	11/12/1973	(1) That section 91.116 of the FAR be changed to agree with the provisions of section 121.653 and the similar requirements of parts 123 and 135 in order that the approach be restricted as well as the landing. (2) That section 91.117 be amended to the effect that in no event shall descent below 200 feet be performed unless landing minimums are present. (3) that while section 91.116(b) clearly states that a landing may not be made unless the visibility is at or above the landing minimum required, nevertheless, in the interests of safety and in order to insure proper interpretation, all conditions requiring a missed approach should be contained in section 91.117 (b). Accordingly, an additional condition should be added to section 91.117(b) to the effect that if landing minimums cannot be maintained, a missed approach must be executed.

A-68-06	FAA and ESSA	1968	CAA/ CNLA	01/01/1975	1. Increase the number of aviation weather observing sites. 2. Vigorous program of quality control of aviation weather observations should be developed. 3. Cloud-height measuring equipment should be provided at all aviation weather observing stations. 4. Additional efforts should be made to standardize the location of weather instruments at airports. 5. Methods should be developed for measuring and forecasting low level wind shear in the terminal area. 6. In order to insure more accurate visibility observations, adequate visibility reference markers (particularly nighttime markers) should be provided for the guidance of observers. 7. Continued efforts should be made to expand the upper-air observing network and to increase the number of rawinsonde ascents to four per day. 8. The weather radar network should be expanded, particularly west of approximately 100 degree west longitude, and weak, obsolete, war-surplus equipment should be replaced with up-to-date, long-range weather radar sets. 9. It is recognized that it is generally impractical to base a staffing plan on the "bad weather" situation. It appears, however, that some revisions or expansions are required, so that a continuous weather watch could be maintained and improved pilot briefing services provided at those locations manned by one person during certain hours. 10. Continue the expansion of the runway visual range (RVR) program including the multiple installations of transmissometers. 11. A means of measuring slant visibility or slant visual range which a pilot would experience on an approach to landing would certainly enhance air safety. 12. In view of the enthusiastic support by the users of the pilot-to-forecaster experimental programs at Kansas City and Washington, it is suggested that serious consideration be given to establishing an operational program on a national basis. 13. The transcribed weather broadcasts (TWEB) network should be expanded to provide coast-to-coast coverage. 14. The pilots automatic telephone weather answering service (PATWAS) should be greatly expanded to provide its service to many additional areas, particularly those areas where live weather briefing may not now be available. 15. There is a need for more pilot weather briefing facilities. 16. Substantial improvements in weather briefings could be realized by the provision of facsimile equipment for all weather briefing facilities. This would also assist in the desired standardization of pilot weather briefing procedures. 17. Additional efforts should be made to improve and standardize weather briefing displays. 18. Provision should be made for additional telephone lines to weather briefing facilities. 19. In order to assist the safety board in accident investigations and for ESSA/FAA quality control purposes, audio recording of pilot weather briefings is advocated. 20. Aviation stands to benefit from information derived from weather satellites. Accordingly, it is considered that special efforts should be made to devise refined techniques and procedures for providing aviation-oriented weather satellite information on a national basis. 21. There continues to be a need for improved delineation of aviation forecast area boundaries. A revision of the present system of delineation should be considered in order to define more precisely the area boundaries – perhaps a reassignment of areas of forecast responsibility to make the boundaries contiguous with state boundaries. 23. We adhere to the belief that a centralized Clear Air Turbulence (CAT) forecasting center should be established, similar to the Severe Local Storms (SELS) unit. Certainly safety, efficiency, and economy would be enhanced by such an establishment. 24. Continued efforts should be made to improve the procedures for obtaining and disseminating in-flight weather information. 25. We are concerned with instructions to forecasters regarding the modifiers to be used for In-flight Advisories (SIGMETS) containing Clear Air Turbulence (CAT) forecasts. Forecasters are directed to use the phrase “moderate or greater” in CAT *forecasts* and may only use “severe” or “extreme” in CAT *reports*. These instructions (in Chapter D-22 of the Weather Bureau Operations Manual) appear to be contrary to preceding instructions (in that Manual) which call for SIGMETS to be issued when (among other things) “severe” or “extreme” turbulence are expected. Unfortunately, “moderate or more turbulence” includes all intensities except “light.” Furthermore, it seems unfair and certainly not very helpful to the pilot not to be apprised of the forecasters thinking and intent in regard to the category of turbulence to be anticipated. 26. There has always been a requirement for more accurate aviation weather forecasts, particularly for the terminal area, and research into improved forecasting methods should continue to be pursued. Research should also be conducted to develop objective methods for measuring or forecasting the intensity of icing and turbulence.
A-68-24	FAA	1968	CAA	09/04/1969	It is recommended that the installation of adverse weather warning devices (light) be encouraged at all airports where official weather observations are taken.

Appendix B

Basic VFR Weather Minimums

Airspace	Flight Visibility	Distance from Clouds
Class B	3 statute miles	Clear of Clouds
Class C	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
Class D	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
Class E Less than 10,000 feet MSL	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
At or above 10,000 feet MSL	5 statute miles	1,000 feet below 1,000 feet above 1 statute mile horizontal
Class G 1,200 feet or less above the surface (regardless of MSL altitude)		
Day, except as provided in section 91.155(b)	1 statute mile	Clear of clouds
Night, except as provided in section 91.155(b)	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
Class G More than 1,200 feet above the surface but less than 10,000 feet MSL		
Day	1 statute mile	500 feet below 1,000 feet above 2,000 feet horizontal
Night	3 statute miles	500 feet below 1,000 feet above 2,000 feet horizontal
Class G More than 1,200 feet above the surface and at or above 10,000 feet MSL	5 statute miles	1,000 feet below 1,000 feet above 1 statute mile horizontal

Appendix C

Evaluation of Matching Procedure

Interviews were conducted with 135 pilots of matching nonaccident flights. The mean number of matches identified per accident was 2.2 for accidents involving IFR flights, and 1.5 per accident for those involving VFR flights. There were no statistically significant differences between the accident and nonaccident groups on the variables used for matching, and the absence of any differences confirmed the soundness of the procedures used to match accident and nonaccident flights.

Aircraft Types

Of the study accidents, 74 percent involved single-engine aircraft and 26 percent involved multiengine aircraft. The nonaccident aircraft group included 72 percent single-engine and 28 percent multiengine airplanes. In comparison, estimates from the 2002 *General Aviation and Air Taxi Activity* (*GAATA*) *Survey*[1] indicated that single-engine airplanes accounted for 69 percent of aircraft involved in GA operations, and multiengine airplanes accounted for 13 percent. Additionally, 93 percent of study accidents involved piston-powered airplanes, 6 percent involved turboprops, and 1 percent involved jet aircraft. The nonaccident group included 90 percent piston-powered aircraft, 7 percent turboprop aircraft, and 2 percent jet aircraft.[2] *GAATA Survey* estimates indicated that piston-powered airplanes accounted for 77 percent of the GA fleet, while turboprops accounted for 3 percent, and jets for 4 percent. See figures C1 and C2.

[1] U.S. Department of Transportation, Federal Aviation Administration, *General Aviation and Air Taxi Activity Survey, Calendar Year 2002* (Washington, DC: FAA, 2004), available at <http://api.hq.faa.gov/pubs.asp>.

[2] Values do not sum to 100 percent due to rounding.

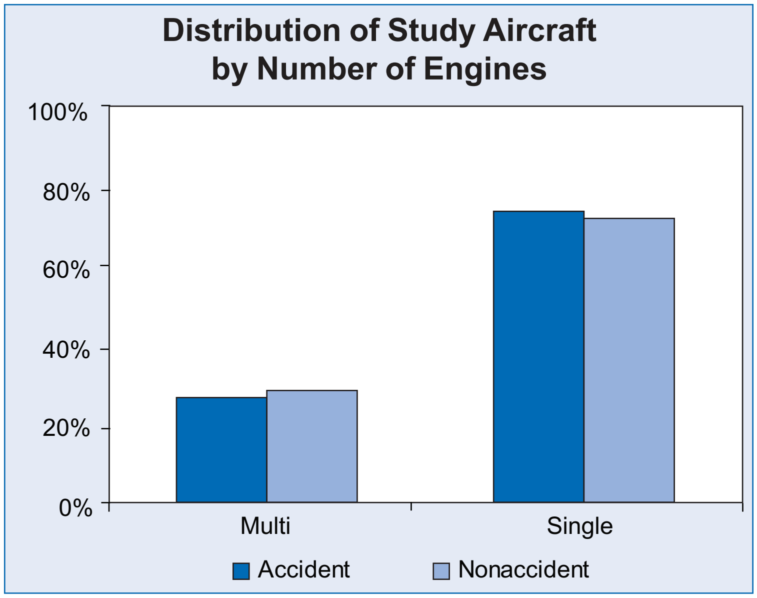

Figure C1

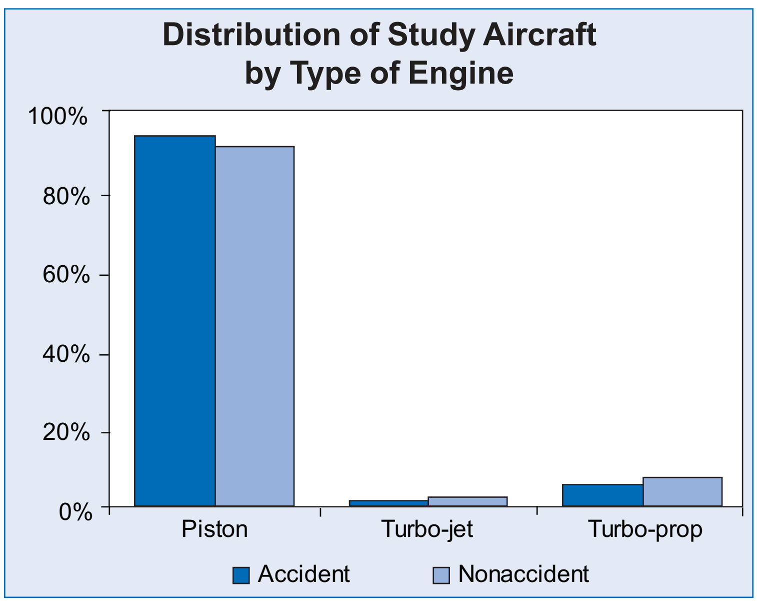

Figure C2

Appendix D

Guided Interview

Departure Point_____ Time_____
Destination _____ Time_____

En route Altitude_____

N-number_____ Aircraft Manufacturer_____ Aircraft Model_____

Do you ☐rent or ☐own ☐other:_____?

Notes:

Purpose of flight
☐Personal Travel ☐Proficiency ☐Flight to or from work, or work-related
☐Pleasure ☐Paid to fly (Instructor, observation, delivery)

Regulation
☐Part 91 ☐Part 135 ☐Part 121

Leg of Trip
☐Inbound ☐Outbound ☐Intermediate ☐Local

Were you familiar with the airplane? ☐Yes ☐No

Were you familiar with the area? ☐Yes ☐No

Flew in the region in the last 6 months? ☐Yes ☐No

What flight rules were you operating under? ☐VFR ☐VFR with flight following
☐ VFR to IFR (filed en route) ☐IFR

if VFR, did you file a flight plan or use flight following? ☐Yes ☐No

Was there more than 1 pilot aboard the aircraft? ☐Yes ☐No

Notes:

Weather Briefing

Did you get a briefing prior to departure? ☐Yes ☐No

If yes, what source? ☐DUATS ☐Flight Service ☐Television ☐ATIS/METAR ☐Internet ☐Other:_____

Did you get more than one briefing? ☐Yes ☐No

Approximate time of last briefing: _____

Did you request weather en route? ☐Yes ☐No

How would you describe the weather you encountered on that flight? _____

Basic Weather: ☐ IFR ☐ MVFR ☐ Convective ☐ VFR – degraded visual reference

Was it better or worse than the forecast? ☐Better ☐Worse ☐Same

Did you have to deviate from your planned route or altitude? ☐Yes ☐No

What type of approach did you do at your destination?
☐Visual ☐ILS ☐Localizer ☐VOR ☐NDB ☐GPS

Basic aircraft equipment ☐VFR only ☐IFR certified

Navigation Avionics ☐ VOR ☐DME ☐ RNAV/LORAN
☐ ADF ☐ GPS (VFR-only) ☐ GPS (IFR en route)
☐ GPS (IFR approach) ☐ Moving Map ☐ Glideslope
☐ Marker Beacon ☐ Other: _____
Comments: _____

Weather equipment ☐ Weather Radar ☐ Storm scope/Strike finder
☐ Structural Anti-ice/De-ice ☐ Other: _____
Is your aircraft certified for known icing? ☐ Yes ☐ No
Comments: _____

Aircraft Control Equipment ☐ Wing-leveler ☐ Autopilot (2 axis)
☐ Autopilot (2 axis, coupled) ☐ Altitude Hold ☐ Yaw Damper
☐ Other:_____
Comments:_____

Additional Avionics ☐ Altitude alert ☐ Radar altimeter
☐ Multifunction Display(s) ☐ GPWS ☐ TCAS
☐ Other:_____
Comments:_____

Pilot Details

Sex ☐Male ☐Female

Certificates: ☐None ☐Student ☐Private ☐Commercial
☐ATP DATE(S): _____

Ratings: ☐SEL ☐MEL ☐SES ☐MES ☐Other:

Instrument Ratings: ☐Airplane ☐Other: _____ DATE(S): _____

Instructor Rating(s)? ☐None ☐Airplane ☐Multi-engine Airplane
☐Instrument Airplane ☐Other:_____

Date of most recent flight review_____

Date of most recent flight instruction_____

Date of most recent instrument competency check (if applicable)_____

Date of most recent instrument flight instruction_____

Date of last medical exam _____

Medical Certificate ☐ First Class ☐ Second Class ☐ Third Class
Waivers/Limitations ☐No ☐Yes If yes, what?

Certificate number (this will be de-identified)_____

Pilot Date of Birth _____

Flight Activity

The rest of my questions have to do with the number of flight hours you have, and you may not have all of the information immediately available. If not, is there a time that I can call you back?

	All A/C	In Type A/C	Night	Actual Instrument	Simulated Instrument
Total Time					
PIC					
Instruction Received					
Last 90 Days					

Appendix E

Supplemental Accident Form

NTSB General Aviation Weather Supplemental Form

1. Accident/Incident Information

Date City State
Aircraft N-number NTSB#
Basic Weather ☐ IFR ☐ MVFR ☐ VFR – with reduced visual reference ☐ Convective

2. Purpose of Flight (Check one)

☐ Personal Travel ☐ Proficiency ☐ Paid to fly (e.g. Instructor, observation, delivery)
☐ Pleasure ☐ Flight to or from work, or work-related ☐ Other:
Comments:
Pilot's connection to the accident aircraft: ☐ Own (full or part) ☐Rent ☐Other:

3. Leg of Trip

☐ Outbound leg ☐ Intermediate leg ☐ Inbound leg ☐ Local Flight
Comments:

4. Weather Briefing

4.1 Pilot received a weather briefing prior to departure ☐ Yes ☐ No Record
4.2 Pilot received more than one weather briefing ☐ Yes ☐ No Record
4.3 Time of last weather briefing (UTC)
4.3 Pilot requested updated weather while en route ☐ Yes ☐ No Record
4.4 Comments:

5. Pilot Experience

5.1 Date of most recent flight review ☐ Could not be determined
5.2 Date of most recent instrument competency check (if applicable) ☐ Could not be determined
5.3 Pilot was familiar with the area ☐ Yes ☐ No ☐ Could not be determined
5.4 Pilot was familiar with the accident aircraft ☐ Yes ☐ No ☐ Could not be determined
5.5 Comments:

6. Pilot Instrument Training

6.1 Total hours of simulated instrument instruction received ☐ Could not be determined
6.2 Total hours of actual instrument instruction received ☐ Could not be determined
6.3 Date of most recent flight instruction ☐ Could not be determined
6.4 Date of most recent instrument flight instruction ☐ Could not be determined
6.5 Comments:

7. Basic Aircraft Instruments (Check one)

☐ VFR-only ☐ IFR certified ☐ Unknown / Destroyed
Comments:

8. Navigation Avionics (Check all that apply)

☐ VOR ☐ DME ☐ RNAV/LORAN ☐ ADF
☐ GPS (VFR-only) ☐ GPS (IFR en route) ☐ GPS (IFR approach) ☐ Moving Map
☐ Glideslope ☐ Marker Beacon ☐ Unknown / Destroyed ☐ Other:
Comments:

9. Weather Equipment (Check all that apply)

☐ Weather Radar ☐ Storm scope/Strike finder ☐ Anti-ice/De-ice Equipment
☐ Unknown / Destroyed ☐ Other:
Was the accident aircraft certified for known icing? ☐ Yes ☐ No ☐ Unknown
Comments:

10. Aircraft Control Equipment

☐ Wing-leveler ☐ Autopilot (2 axis) ☐ Unknown / Destroyed
☐ Autopilot (2 axis, coupled) ☐ Altitude Hold ☐ Yaw Damper
☐ Other:
Comments:

11. Additional Avionics

☐ Altitude alert ☐ Radar altimeter ☐ Multifunction Display(s)
☐ GPWS ☐ TCAS ☐ Unknown / Destroyed
☐ Other:
Comments:

12. Did the pilot declare an emergency, communicate a problem, or request help?

☐ Yes ☐ No

if Yes, briefly explain

13. Additional Information (Use this space to add any additional information that did not fit in the above spaces)

14. Administrative information

Investigator Date
Please complete and return within 30 days of the accident.

Appendix F

A Comparison of Forecast and Actual Visibility Conditions for Study Accidents

Accidents were included in this study if they took place in IMC or marginal VMC or if they were preceded by a loss of visual reference or encounter with weather. One step in the analysis was to determine if pilots could have anticipated the weather conditions they experienced based on the weather forecasts that were available before their departure.

Aviation weather forecasts provide several types of information, including horizontal visibility, ceiling heights, cloud coverage, precipitation types, wind, and convective activity. The decision that a forecast is consistent with actual conditions is somewhat subjective, and a difference that is acceptable to one person may not be acceptable to another. For this study, the FAA's legal definition of VFR minimums was used to classify the forecast conditions into categories of VFR or IFR. VFR minimums dictate the minimum ceiling and visibility conditions for a pilot to fly without an IFR flight plan. While the threshold between VFR and IFR varies somewhat depending on the type of airspace and time of day, VFR conditions are generally present when the cloud ceiling[1] is 1,000 feet or greater and the horizontal visibility is 3 miles or greater. IFR conditions exist when either horizontal visibility or cloud ceilings are less than these minimums.

To determine the forecast conditions for each accident, Safety Board meteorologists obtained Sierra AIRMETs that were released immediately before the accident airplane's departure time for the region surrounding the accident location. (The Sierra AIRMET describes IFR conditions and mountain obscurations.) Staff then plotted the Sierra AIRMETS and determined whether the accident site was located within its boundaries. When an accident site was within the boundaries of the IFR AIRMET, the forecast was classified as IFR; otherwise it was classified as VFR.

The actual conditions at the time and location of the accident were determined from the Safety Board's factual report. As part of the factual report, the investigator assigns basic weather conditions as either IMC or VMC.

Table F1 provides an overview of the forecast and actual conditions for the 72 accidents in the study. In terms of forecast quality, actual conditions matched forecast conditions in 61 percent of cases. Within the 39 percent of cases in which the forecast did not match the actual conditions, the visibility conditions were "better" than forecast (that is, forecast IFR, actual VFR) in 39 percent, and were "worse" than forecast (that is, forecast VFR, actual IFR) in 61 percent of cases.

[1] Ceiling in this case is defined as the lowest cloud layer of broken (BKN) or greater coverage.

Table F1

Forecast and Actual Conditions for the Study Accidents

Forecast		Actual: VFR	Actual: IFR	Actual: Total
	VFR	6 (8.3%)	17 (23.6%)	23 (31.9%)
	IFR	11 (15.3%)	38 (52.8%)	49 (68.1%)
	Total	17 (23.6%)	55 (76.4%)	72

Using FAA definitions as criteria for evaluating the accuracy of the forecasts suggests that in approximately 25 percent of all accident cases, the actual conditions were worse than predicted. A few of the many possible explanations include the following:

1. Forecasts of IMC or VMC are issued from the perspective of someone on the ground. In-flight conditions also depend on the operating altitude.
2. The weather conditions may have been isolated to an area so small that an AIRMET was not warranted. A Sierra AIRMET is issued for ceilings less than 1,000 feet and/or for visibility less than 3 miles affecting over 50 percent of an area at one time, or for extensive mountain obscuration for an area of at least 3,000 square miles.
3. Using this verification methodology, a fairly small deviation between the forecast and actual conditions could result in a change in classification. For example, if the ceiling was forecast to be 1,000 feet, and the actual ceiling was 900 feet, it would be classified as a change from VFR to IFR conditions.

The term marginal VFR or MVFR is sometimes used to refer to conditions that are near the VFR minimums. MVFR refers to conditions in which visibility is between 3 and 5 miles or when ceiling height is between 1,000 and 3,000 feet. At present, the FAA's use of the term marginal VFR is limited to the section of an area forecast corresponding to the period of time more than 6 hours after the time of forecast issuance.

A closer look at the forecast and actual data reveals that in 4 of the 23 cases where VMC was forecast, and in 6 of the 49 cases where IMC was forecast, the actual conditions fell into the definition of MVFR. In these cases, actual conditions were closer to the forecast than the dichotomous categorization of IFR and VFR would suggest.

Appendix G

Study Accidents

	NTSB Accident Number	Date	Location	Aircraft Registration	Make	Model	Accident Severity
1	IAD03FA069	Aug 02, 2003	Galion, OH	N577SK	Piper	PA-34-200T	Fatal
2	CHI03FA246	Aug 05, 2003	Clarkýeld, MN	N4577T	Piper	PA-28-180	Fatal
3	NYC03FA176	Aug 06, 2003	Pleasantville, PA	N28788	Grumman	AA-5B	Fatal
4	IAD03FA070	Aug 08, 2003	Factoryville, PA	N6373C	Piper	PA-32-300	Fatal
5	CHI03LA267	Aug 19, 2003	Hammond, MN	N1812S	Beech	BE-76	Non-fatal
6	MIA03FA167	Aug 21, 2003	Clearwater, FL	N93DC	Piper	PA-31	Fatal
7	CHI03FA296	Aug 28, 2003	Grand Marais, MN	N285V	Beech	58P	Fatal
8	CHI03FA291	Sep 01, 2003	Uniondale, IN	N8018J	Beech	B36TC	Fatal
9	CHI03LA315	Sep 22, 2003	Chanute, KS	N122CC	Piper	PA-24-250	Non-fatal
10	NYC03FA205	Sep 27, 2003	Concord, MA	N963LP	Cessna	182T	Fatal
11	SEA04LA001	Oct 02, 2003	Blakely Island, WA	N2695S	Cessna	340	Non-fatal
12	SEA04FA009	Oct 20, 2003	Seaside, OR	N136SB	Beech	A36	Fatal
13	ATL04FA027	Oct 26, 2003	Spartanburg, SC	N7799Y	Piper	PA-30	Fatal
14	CHI04FA025	Nov 02, 2003	Hutchinson, KS	N6107Z	Commander	114TC	Fatal
15	FTW04FA022	Nov 16, 2003	Tolar, TX	N777SG	Cessna	210M	Fatal
16	LAX04GA051	Nov 21, 2003	Big Bear City, CA	N7292W	Piper	PA-28-180	Fatal
17	SEA04FA022	Nov 25, 2003	Warren, OR	N10BX	Beech	S35	Fatal
18	MIA04FA029	Nov 27, 2003	Jacksonville, FL	N698X	Swearingen	SA-26-AT	Fatal
19	FTW04FA036	Dec 04, 2003	Harrison, AR	N350JL	Beech	S35	Fatal
20	LAX04LA058	Dec 04, 2003	San Diego, CA	N15C	Cessna	525	Non-fatal
21	ATL04FA045	Dec 04, 2003	Morlan, GA	N85BK	Beech	B200	Fatal
22	LAX04FA061	Dec 07, 2003	Chino Hills, CA	N16264	Piper	PA-28R-200	Fatal
23	ATL04FA049	Dec 10, 2003	Vestavia Hills, AL	N441W	Cessna	441	Fatal
24	ATL04FA051	Dec 11, 2003	Greeneville, TN	N1592T	Cessna	414	Fatal
25	SEA04LA026	Dec 11, 2003	McMinnville, OR	N29CV	Upright	RV-7A	Fatal
26	LAX04FA066	Dec 14, 2003	Claremont, CA	N6887L	Cessna	421C	Fatal
27	ANC04FA015	Dec 14, 2003	Tonopah, NV	N4674A	Cessna	P210N	Fatal
28	LAX04FA081	Dec 15, 2003	Corona, CA	N61303	Cessna	150J	Fatal
29	FTW04FA044	Dec 15, 2003	Mena, AR	N7929D	Beech	H-35	Fatal
30	CHI04FA044	Dec 17, 2003	Brooklyn, IA	N3733W	Piper	PA-32-260	Fatal
31	CHI04FA043	Dec 17, 2003	Daytona Beach, FL	N155BM	Piper	PA46-500TP	Fatal
32	ATL04FA056	Dec 17, 2003	Sanford, NC	N9562L	Cessna	206H	Fatal
33	LAX04LA074	Dec 20, 2003	Angwin, CA	N20480	Beech	B55	Non-fatal
34	SEA04LA029	Dec 22, 2003	Missoula, MT	N181AM	Beech	58P	Non-fatal
35	LAX04FA077	Dec 24, 2003	Avalon, CA	N3747U	Piper	PA-34-200T	Fatal
36	SEA04LA030	Dec 25, 2003	Elk City, ID	N1363U	Cessna	172M	Non-fatal

	NTSB Accident Number	Date	Location	Aircraft Registration	Make	Model	Accident Severity
37	SEA04FA032	Jan 01, 2004	Glasgow, MT	N3171S	Cessna	182G	Fatal
38	FTW04FA052	Jan 01, 2004	Dallas, TX	N4104B	Bellanca	17-30A	Fatal
39	SEA04FA031	Jan 01, 2004	Cave Junction, OR	N53505	Piper	PA-44-180	Fatal
40	FTW04FA054	Jan 02, 2004	Beaumont, TX	N396HP	Piper	PA-32R-301	Fatal
41	CHI04LA052	Jan 02, 2004	Fishers, IN	N21992	Piper	PA-32RT-300	Non-fatal
42	DEN04FA035	Jan 03, 2004	Cortez, CO	N700SR	Rockwell	690A	Fatal
43	CHI04FA055	Jan 10, 2004	Baudette, MN	N5787J	Cessna	182P	Fatal
44	LAX04LA092	Jan 11, 2004	Vacaville, CA	N77S	Cessna	140	Non-fatal
45	MIA04CA040	Jan 14, 2004	Fort Meade, FL	N453MC	Cessna	210L	Non-fatal
46	FTW04FA062	Jan 15, 2004	Willow Park, TX	N7252X	Beech	B36TC	Fatal
47	LAX04FA096	Jan 19, 2004	Grass Valley, CA	N99LR	Cessna	172K	Fatal
48	MIA04FA045	Jan 19, 2004	Fort Pierce, FL	N298PA	Piper	PA-28-181	Fatal
49	SEA04LA038	Jan 28, 2004	Rigby, ID	N734CB	Cessna	172N	Non-fatal
50	MIA04FA049	Jan 31, 2004	Homestead, FL	N75GC	Beech	C90	Fatal
51	LAX04FA113	Jan 31, 2004	Laupahoehoe, HI	N5637C	Cessna	414A	Fatal
52	DEN04FA043	Feb 06, 2004	Walcott, WY	N51192	Cessna	T206H	Fatal
53	CHI04LA064	Feb 07, 2004	Lone Rock, WI	N5039S	Piper	PA-28R-200	Non-fatal
54	ATL04FA075	Feb 11, 2004	Alma, GA	N6473J	Piper	PA-28-180	Fatal
55	ANC04LA022	Feb 14, 2004	Crescent City , FL	N98WB	Thorp	T-18	Fatal
56	CHI04FA071	Feb 16, 2004	Rozel, KS	N735RD	Cessna	182Q	Fatal
57	CHI04FA069	Feb 17, 2004	Rich Hill, MO	N7876W	Piper	PA-28-180	Fatal
58	FTW04FA079	Feb 22, 2004	Valley Spring, TX	N6175Y	Cessna	210N	Fatal
59	ATL04FA077	Feb 23, 2004	Arlington, AL	N9103Z	Piper	PA-46-310P	Fatal
60	LAX04FA139	Feb 27, 2004	Pine Mtn Club, CA	N7687J	Piper	PA-28R-180	Fatal
61	CHI04LA085	Mar 08, 2004	Dubuque, IA	N105FS	Cessna	172R	Non-fatal
62	MIA04FA060	Mar 15, 2004	Spring Hill, FL	N8148G	Cessna	182P	Fatal
63	LAX04FA162	Mar 16, 2004	Los Angeles, CA	N1148V	Mooney	M20K	Fatal
64	NYC04FA092	Mar 21, 2004	Harlan, KY	N8173U	Piper	PA-32R-301	Fatal
65	ATL04LA087	Mar 28, 2004	Bay Minette, AL	N605AM	Alarus	CH2T	Non-fatal
66	NYC04FA100	Apr 02, 2004	Harrietstown, NY	N4686J	Piper	PA-28R-180	Fatal
67	LAX04FA177	Apr 04, 2004	Ukiah, CA	N4130D	Piper	PA-32R-301T	Fatal
68	DEN04FA057	Apr 06, 2004	Burlington, CO	N3524Y	Cessna	182F	Fatal
69	MIA04LA070	Apr 10, 2004	N. Lauderdale, FL	N916LJ	Cirrus	SR22	Non-fatal
70	ATL04FA093	Apr 12, 2004	North Augusta, SC	N364ME	Cessna	182S	Fatal
71	SEA04LA071	Apr 17, 2004	Gibbonsville, ID	N5XK	Keller	Prospector FK1	Non-fatal
72	ATL04LA097	Apr 23, 2004	Oakland, TN	N511WD	Durr	Lancair Legacy	Fatal