National Aviation Weather Program Mid-Course Assessment

Accident Reduction Trends Confirm Value of Coordinated R&D Programs

Office of the Federal Coordinator for
Meteorological Services and Supporting Research

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NATIONAL AVIATION WEATHER PROGRAM COUNCIL

Cover: Project Cloudline Echo; photo courtesy NOAA/AOML/Hurricane Research Division.

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Prepared by the

Office of the Federal Coordinator for
Meteorological Services and Supporting Research

for the

Federal Committee for Meteorological Services
and Supporting Research

and the

National Aviation Weather Program Council

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Foreword

This mid-course assessment gives me both cause to celebrate and cause to renew and re-energize our efforts to reduce the weather-related risks to aviation safety. I can celebrate because *we are making real progress*. The analyses confirm much anecdotal evidence that the coordinated efforts and diverse partnerships that constitute the national aviation weather program initiatives are making a real difference in accident rates. The investments in research and development (R&D) and implementation of products, services, and systems are paying off. But we have not yet reached our goal. If we fail to sustain the efforts so effectively started, the trends charted here will not be sustained. A national safety goal that is within reach could slip from our grasp. This assessment tells us where trouble spots remain and points to ways we can overcome them, while furthering the work that has started us toward success.

In 1995, a study committee of the National Research Council called for coordinated federal action to improve weather services for aviation users and strengthen the R&D base required for sustained improvement. The committee's report, *Aviation Weather Services: A Call for Federal Leadership and Action*, correctly identified the Federal Aviation Administration as the lead agency for this coordinated effort. It also noted where the roles and missions of other federal agencies and the private sector gave them shared responsibilities as well as opportunities to contribute.

The framework for an invigorated and coordinated national effort in aviation weather was established in the 1997 *National Aviation Weather Program Strategic Plan*. This document identified strategic elements and defined the roles and missions of participating federal agencies with respect to those elements, while delegating implementation of the plan to the agencies and their university and industry partners. A second tier of coordination was established by *National Aviation Weather Initiatives* in 1999. Both of these documents were prepared by the Joint Action Group for Aviation Weather and approved by the National Aviation Weather Program Council, which is chaired by the Federal Coordinator.

The Aviation Weather User Forum in 2000 set the stage for strong partnering among the federal agencies, the aviation community, and the commercial sector that serves the aviation community. This forum also provided a starting point for the Office of the Federal Coordinator for Meteorological Services and Supporting Research to begin compiling details of individual projects and their relationship to the national aviation weather initiatives established the preceding year. The forum provided many examples of partnerships between the public and private sectors, as well as among federal agencies, that were producing results with evident benefits for users. The first compilation of this project-level data was released as the *National Aviation Weather Initiatives Final Baseline Tier 3/4 Report* in 2001.

The aviation industry has continued to play a strong role in the national programs and initiatives as well as having the principal role in commercializing and using the resulting technology. The university research community has contributed greatly to aviation weather R&D. Aviation associations and others serving the aviation community (university-based and commercial providers) have played a major role in education, training, and outreach. The positive consequences of these efforts are already evident in the declining trends for weather-related accidents in general aviation, which are analyzed in this report. Without the broader partnerships into which associations, universities, and the aviation industry have entered with the agencies participating in the National Aviation Weather Program Council, the successes we can now document would not have happened.

We are at a midpoint in the original ten-year effort—a good perspective from which to assess where progress is being made and where more attention may be needed. In my roles as the Federal Coordinator and Chair of the National Aviation Weather Program Council, I will use this mid-course assessment, plus the Tier 3/4 review and analysis process, to coordinate continued progress in our national aviation weather program initiatives.

I intend to work with the agency partners in the Federal Committee for Meteorological Services and Supporting Research, the National Aviation Weather Program Council, and the Committee for Aviation Services and Research to ensure that these areas receive appropriate attention. In particular, I want to thank the Chair and members of the Committee for Aviation Services and Research for supporting this mid-course assessment.

Samuel P. Williamson
Federal Coordinator for Meteorological Services
and Supporting Research

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Executive Summary

This report presents a mid-course assessment of progress toward the goal of reducing weather-related fatal accidents by 80 percent over ten years. In February 1997, the White House Commission on Aviation Safety and Security recommended an 80 percent reduction in fatal aviation accidents from all causes as a ten-year national goal. In its 1999 report on *National Aviation Weather Initiatives*, the National Aviation Weather Program Council identified initiatives being pursued by federal agencies in collaboration with their industry and university partners. The *Initiatives* report also discussed an 80 percent reduction in weather-related accidents as an overall measure of success. To assess progress toward this goal, this report examines trends in weather-related accidents for clearly defined categories of aircraft and weather hazards. In each category, an 80 percent reduction from the average accident rate just before and during 1997 is used as a benchmark for assessing success in reducing accident risk.

Accident Risk and Weather Hazard Analysis

The accident risk analysis uses accident data from the National Transportation Safety Board (NTSB). Federal Aviation Administration (FAA) estimates of total departures or total flight-hours are used to calculate accident rates from the NTSB accident counts. The aviation community is divided into three categories used by the NTSB: major air carriers (aircraft regulated under Part 121 of the Federal Aviation Regulations), smaller aircraft in revenue service (regulated under Part 135), and general aviation (regulated under Part 91).

For all three regulatory categories taken together, the average number of weather-related fatal accidents in the base years for determining the 80 percent reduction goal (1994–96) was 112. In 2001, the number of weather-related fatal accidents was 45, and the three-year moving average (1999–2001) was 70. On this broad basis, substantial progress has been made toward the goal of an 80 percent reduction (no more than 22 fatal accidents per year in all categories). But the goal has not yet been reached, and continuation of ongoing efforts is essential to reach it by 2006. To direct these efforts, the mid-course assessment has examined the accident experience over time in each of the three aviation categories and, within them, the success in reducing the risks from specific weather factors.

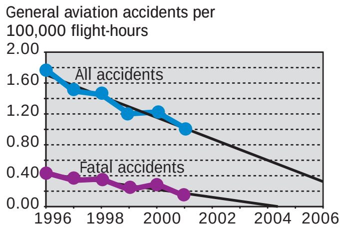
Weather-related fatal aviation accidents decreased from an average of 112 per year in 1994–96 to just 45 in 2001.

Fatal weather-related accidents for the major air carriers are too infrequent (only two accidents from 1995 through 2001) to assess statistical trends. However, if the data for *all* weather-related accidents are used as an indicator, further improvement will be needed to reduce the weather-related accident rate for major carriers by 80 percent. The category of weather hazards that contributes most to these accidents includes turbulence and convection hazards (such as microbursts, downdrafts and updrafts, gusts, or wind shear).

A major piece of good news from the hazard assessment is the steady decline since 1996–97 in weather-related

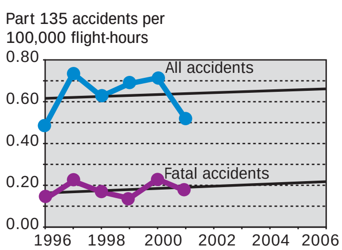
Weather-related accidents—fatal and nonfatal—for general aviation are on strong downward trends. With continued investment and support from all partners, an 80 percent reduction can be achieved for this aviation category by 2007.

accidents for general aviation aircraft (Part 91). The trend for fatal weather-related accidents for all weather factors is on track to exceed the 80 percent reduction benchmark, as is the trend for fatal accidents in five of the six weather hazard categories used in this report.



Only the category for temperature and lift hazards for Part 91 is not on trend to achieve an 80 percent reduction. The weather factor that dominates this category, for both general aviation and smaller air carriers, is *high density altitude*. This flight performance factor takes into account the effect of temperature on the amount of air flowing over the camber of an aircraft's wing, particularly during takeoff and landing at higher elevations. High humidity in hot weather exacerbates the effect by decreasing engine performance.

The accident data for smaller air carriers in revenue service (Part 135 aircraft) are not yet on clear downward trends. In fact, the rate trends for all weather-related accidents and for fatal weather-related accidents for Part 135 are nearly flat to slightly increasing. The analysis by weather hazard category indicates that the fatal accident rates for these aircraft in four of the six hazard categories are not trending down enough to achieve an 80 percent reduction target. In two categories—precipitation (non-icing) hazards and icing conditions—the trends are increasing. In all six categories, the data series for all weather-related accidents confirm a general pattern: accident rates for Part 135 aircraft are not yet trending toward the reduction benchmark.



Mid-Course Assessment

In 2001, the *National Aviation Weather Initiatives Final Baseline Tier 3/4 Report* presented a project-by-project review of the efforts recently implemented or in development on each of the national aviation weather initiatives identified in the 1999 report. Section 4 of this report begins with an updated overview of these projects, organized by lead partner and by five categories of principal product type: weather product development; weather product dissemination; education, training, and outreach; cockpit displays; and decision support systems and capabilities.

Section 4 then assesses this portfolio of programs and projects in relation to the noteworthy trends in accident rates noted above. Sections 4 and 5 develop the following conclusions and recommendations for achieving the 80 percent reduction goal for fatal aviation accidents.

Sustaining Risk Reduction Success in General Aviation

The limited evidence available suggests that a combination of factors underlies the strong downward trends in weather-related accident rates for general aviation. These factors include:

1. The revolution in weather information products flowing from the National Weather Service Modernization in the 1990s
2. The aviation-specific systems and products whose development and implementation have been sponsored and funded by the FAA through its Aviation Weather Research Program (as well as various predecessor and coordinated programs)
3. Advances in information communication systems and weather product dissemination services, which have given general aviation pilots access to these improved products and services
4. Acquisition by general aviation pilots of the knowledge needed to use the available information to avoid hazardous weather conditions.

Education and training for the general aviation pilot is the linchpin that ties together the first three factors into a success story. Statistics from the Aircraft Owners and Pilots Association on course attendance and video seminar sales support anecdotal information from association staff on the positive response of the general aviation community to improved access to weather information products and services. The popularity of the Aviation Digital Data Service (ADDS) website shows that the aviation community is embracing the use of improved aviation weather products.

Conclusion 1. The partnerships through which aviation and weather associations, the aviation industry, and federal agencies have provided education, training, and outreach to the general aviation community have made a strong beginning in reducing the risks of weather-related accidents in the Part 91 aircraft regulatory category. The ambitious goal of an 80 percent reduction in the fatal accident rate for general aviation appears attainable by 2006 if these efforts can be expanded to reach every general aviation pilot. The general aviation community will also need to know about new products and services that are becoming available, such as those resulting from university-based research and development (R&D). The development and implementation programs for these new products and services must be sustained, despite fiscal constraints and tight budgets.

Recommendation 1. The partnerships for education, training, and outreach should be expanded to include more collaboration among entities offering courses and materials. The aim should be to provide every general aviation pilot with knowledge of all weather hazards that the pilot is likely to encounter, together with the information and advisory services to deal with them safely. To sustain the accident reduction trends, these education and outreach efforts must keep pilots informed about the new products and services emerging from R&D to the implementation phase.

Reducing Accident Trends for Smaller Commercial Carriers

For aviation weather technology to make a difference for smaller carriers in revenue service (Part 135 aviation), the information from these advances in weather observation and forecast products must be delivered to the Part 135 pilot. Furthermore, these information dissemination solutions must fit within the cost constraints under which Part 135 aviation services operate. The FAA Safe Flight 21 program is a promising initiative that could meet these challenging requirements. As already demonstrated in the Alaskan Region Capstone program, Safe Flight 21 will include a communications uplink capability, Flight Information Services–Broadcast (FIS-B). FIS-B can deliver current weather information to the cockpit, viewable on the same multifunction display the pilot will use for traffic awareness and terrain visualization in all visibility conditions. Although FIS-B appears to offer a long-term solution for getting current weather information en route, along with terrain visualization, to the Part 135 pilot (as well as to general aviation pilots) at affordable costs to the industry, most of the National Airspace

Many Part 135 aircraft are smaller planes, like this commercial carrier of passengers and cargo in Alaska. Photo courtesy Wings of Alaska Airlines, © Mike Mastin.

System will not have FIS-B coverage until after 2007. Thus, the program's major impact on weather safety will not be felt until after the 2006 milestone for achieving the 80 percent accident reduction goals.

Because of the diversity of operations and services that are regulated under Part 135, a more detailed analysis for this category is needed of the weather factors involved in weather-related accidents, grouped by similar types of aviation service. The detailed analysis should include an assessment of aviation weather program elements, including both R&D and implementation efforts, that can lessen the risks identified for specific segments within the Part 135 aviation category. In the interim, the Part 135 community needs to be well informed about the weather information sources already available or nearing implementation.

Part 135 includes aircraft used for contract services that require flying in hazardous weather, such as medical evacuation and emergency rescue flights. Photo courtesy Air Ambulance Specialists, Inc.

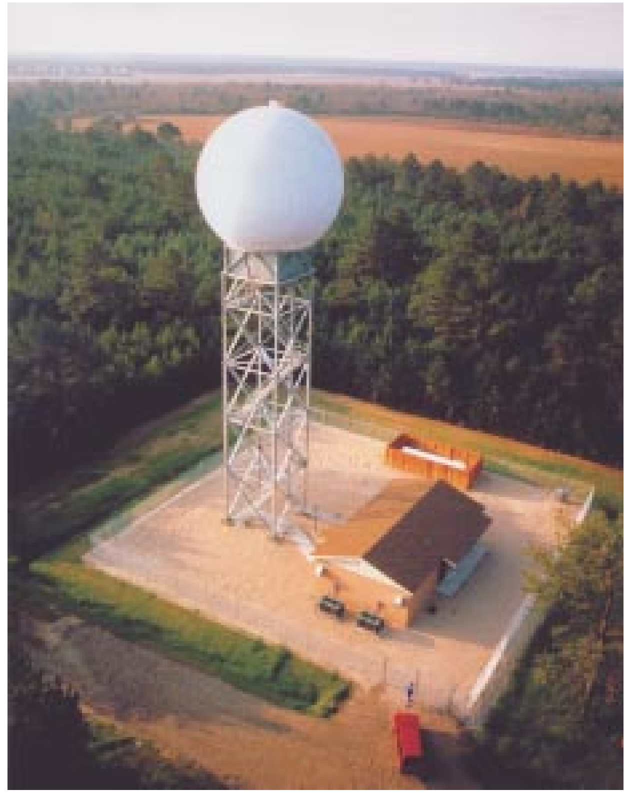
Conclusion 2. Part 135 aviation is constrained by factors that distinguish it from either general aviation or major commercial carriers. The range of operations and types of services offered in this category vary widely and include some that are inherently more hazardous than general aviation or commercial air carrier flights. Early results from the Alaskan Region Capstone demonstration, part of the FAA's Safe Flight 21 program, indicate that the technology exists to lower weather-related accident risks for at least some Part 135 operations. Unfortunately, the current deployment schedule for Safe Flight 21 will not provide weather information coverage across most of the National Airspace System until the 2007–12 time frame. A more detailed analysis of weather-related accidents involving Part 135 aircraft will be needed to determine how different segments of this diverse category are affected by various weather hazards and what actions could be taken to lessen the risks and reduce accident rates.

Recommendation 2. A more detailed analysis, probably employing a case analysis approach, should be conducted to assess the impact of weather hazards on specific segments of the aviation community regulated under Part 135. As an interim measure, a special effort should be made to ensure that both pilots and owners of Part 135 aircraft are aware of the weather information infrastructure and services available to them.

- Prior to deployment of Flight Information Services–Broadcast under the Safe Flight 21 program, available information sources and services, such as the Aviation Digital Data Service and the Flight Information Services Data Link, can be emphasized in the outreach program.
- As the Flight Information Services–Broadcast becomes available via the Safe Flight 21 Universal Access Transceiver communications uplink, training in this information service should be emphasized.

Reducing Risk from Turbulence and Convection Hazards

Turbulence and convection hazards account for substantially more than half of all weather-related accidents each year involving aircraft of the major air carriers. Although very few of these accidents cause fatalities, weather factors in this hazard category are cited each year in multiple fatal accidents involving general aviation and smaller



The FAA has installed Terminal Doppler Weather Radar at high-activity airports to detect weather hazards for departing and landing aircraft. Photo courtesy FAA.

commercial carriers. For both en route and departure/landing service areas, a number of projects in progress can contribute to reduce the risks from these hazards.

The Graphical Turbulence Guidance product for aviation forecasters is now implemented for flight levels down to 20,000 feet. The FAA's Aviation Weather Research Program plans to include guidance for turbulence down to 10,000 feet, which will increase its value for Part 135 and general aviation flights. Observational data on in-flight turbulence from the In-Situ Turbulence Algorithm is planned for implementation on a limited number of commercial aircraft by incorporating it into their Aircraft Condition Monitoring System. The automated data download via this system will eventually help to improve the Graphical Turbulence Guidance product and validate turbulence prediction models used by aviation weather forecasters. Methods for detecting clear-air turbulence ahead of commercial aircraft are also being researched.

Several observing systems already in limited deployment at the nation's airports provide air traffic controllers, traffic managers, and flight service station specialists with information about these weather hazards in the terminal area and surrounding airspace. Among these are the FAA's

Weather System Processor, Medium Intensity Airport Weather System, Terminal Doppler Weather Radar, and improved Low Level Windshear Alert System. Models and other forecasting tools for nowcasts (predictions for current conditions to a few hours in the future) will aid in predicting when and where these hazards may be encountered. Flight information services uplinks and other information dissemination systems will help deliver alerts to pilots in near-real time.

Continued investment in these R&D and implementation programs is essential to reaping the benefits they offer for reducing aviation risks from turbulence and similar wind hazards. The risk from these hazards in all three aircraft regulatory categories shows that completion of the work in progress is a worthwhile R&D investment for the nation.

Conclusion 3. No single sensor system or forecast improvement will address the entire range of conditions, both en route and in the terminal area, that produce turbulence and convection hazards. Nevertheless, a sustained effort can put new technology in place, assess its effectiveness, and ensure full implementation of products and services with proven efficacy. A number of programs that are likely to improve detection, forecast, and warnings about these hazards are in or nearing the implementation stage.

Recommendation 3. Investment should continue in R&D and implementation on projects that will contribute to timely observations, forecasts, and warnings of turbulence and convection phenomena, both en route and near the terminal area.

Reducing Risk from High Density Altitude

The factors that contribute to accidents involving high density altitude are well understood. If general aviation and Part 135 pilots have accurate information about temperatures and relative humidity in their departure and landing patterns, they can use the performance parameters of their particular aircraft and flight load to calculate and compensate for the density altitude. Thus, this weather hazard can in principle be avoided. However, the rate trends for accidents in which high density altitude is cited indicate that pilots are still having problems with the multifactor computations and considerations required to avoid density altitude problems.

Conclusion 4. The hazard of high density altitude can be addressed, if the pilot has accurate observations or forecasts and a decision support tool that receives this information and combines it with the specifications and running condition of the aircraft. The pilot must also have the training to understand the implications of advice or guidance provided by this decision support capability.

Recommendation 4. A review should be undertaken of the circumstances contributing to aviation accidents in which the National Transportation Safety Board has cited high density altitude as a factor. This review should assess the tools currently available to Part 91 and Part 135 pilots to assess density altitude and related aircraft performance parameters, as well as the weather information products, decision support capabilities, or education and training resources that could be provided or improved to reduce the risk from this weather hazard.

Risk Reduction for Other Weather Factors

The annual statistics on weather-related aviation accidents identify a number of additional weather factors that are cited each year in multiple accidents, particularly for general aviation aircraft. Although the frequency of citation for these factors is on a downward trend for the reporting period analyzed in this assessment, sustaining these trends will require continued support for programs and initiatives that are addressing these factors. Examples of such factors discussed in the portfolio analysis include fog and low ceiling (both in the ceiling and visibility service area) and terminal area winds.

Conclusion 5. Curtailment or delays in implementation of useful new products, services, and systems could jeopardize achievements in accident reduction that seem

Restricted visibility can hide other aircraft as well as dangerous terrain. © AOPA, all rights reserved.

within reach if we stay the course. Continued support is essential for these efforts, which are nearing the point of producing real returns and achieving a national safety priority.

Recommendation 5. Investment should be sustained for aviation weather projects and programs whose results are likely to further reduce the risks from weather hazards that continue to be cited in aviation accidents. All the partners whose joint efforts in the past have made possible the progress documented in this assessment must continue their commitments and strengthen their collaborations.

Technology exists to display current weather information graphically to the pilot en route. The challenge is to make the information available to every aircraft throughout the National Airspace System. Photo courtesy FAA Capstone program.

Sustaining R&D to Continue Improving Aviation Safety

Many of the projects included in the overview of current programs and initiatives are indirectly relevant to reducing the risks from multiple weather hazards because they provide general supporting capability. For example, dissemination systems or decision support and cockpit display infrastructure are needed to communicate turbulence information to pilots. In principle, these same systems should be communicating and processing information on all the other weather hazards the pilot is facing, along with other aviation safety information. (The Safe Flight 21 program described above illustrates this integrated approach.) In addition, many aviation weather projects either have already contributed to reducing accident rates or will sustain existing achievements as implementation expands throughout the National Airspace System. Terminal and en route icing forecast products, as well as de-icing decision support systems, are among the examples in this category. Other projects address hazards that have not yet shown up in NTSB accident statistics. For example, international flights by U.S. aircraft need technology to detect and forecast volcanic ash plumes aloft, even though volcanic ash plumes have not (yet) been cited as a factor in the NTSB reports, which cover only the National Airspace System.

To illustrate how projects and initiatives in each area complement and leverage one another, Section 4 includes highlights of representative programs from each of the five aviation weather product areas. New weather information products must be disseminated to end users who have been trained to use them correctly. As the information available increases, well-designed human-machine interfaces are necessary to convey the right information at the right time without distraction or confusion. Decision support capabilities and systems can integrate and interpret these multiple data items into a coherent "situational awareness" for the user.

Conclusion 6. The combined and complementary effects of implemented aviation weather R&D have produced substantial and continuing benefits for the entire aviation industry. Those benefits are passed on to passengers and consumers as increased safety during air travel and improved efficiency and access in the air transport of passengers and cargo. To continue the promising trends—and to overcome the remaining challenges—in reducing weather-related aviation risks identified in this assessment will require sustaining the R&D and implementation programs in progress.

Recommendation 6. The investments in national aviation weather programs and initiatives should be supported and promoted as an effective investment in the nation's future.

1

Introduction

In April 1997, the National Aviation Weather Program Council (NAW/PC) approved and published a *National Aviation Weather Program Strategic Plan*, which had been developed by the council's Joint Action Group for Aviation Weather. This strategic plan was the first step in a federal agency response to the challenge for improved aviation weather safety set forth in a National Research Council report, *Aviation Weather Services—A Call for Federal Leadership and Action* (NRC 1995). The Federal Coordinator, who serves as Chair of the NAW/PC, has coordinated the activities to support and implement the strategic plan. These activities draw on the resources of the Joint Action Group for Aviation Weather and the Office of the Federal Coordinator for Meteorological Services and Supporting Research (OFCM).

In February 1997, the White House Commission on Aviation Safety and Security recommended a national goal for government and industry of reducing the rate of fatal aviation accidents by a factor of five (an 80 percent reduction) within ten years. Safety research and technology improvements were recognized as essential elements in achieving this goal. Subsequently, both the Federal Aviation Administration (FAA), as the lead federal agency for aviation weather safety, and the National Aeronautics and Space Administration (NASA) adopted the 80 percent reduction goal in their strategic plans.

The next major step toward coordinating the many federal and nonfederal programs relevant to improving aviation weather safety was another report prepared by the Joint Action Group for Aviation Weather, *National Aviation Weather Initiatives*. It was approved by the NAW/PC and released in February 1999. Besides identifying ongoing and planned initiatives, this report discussed the 80 percent reduction goal and suggested that a reduction in weather-related accidents, as shown by National Transportation Safety Board (NTSB) accident statistics, could be used as an overall measure of success for the portfolio of aviation weather initiatives (OFCM 1999).

In the 1997 strategic plan, the NAW/PC took responsibility for overseeing periodic reviews of the program to provide mid-course corrections as needed, as well as to maintain momentum as the plan progressed. The OFCM was assigned a supporting role in providing analyses, summaries, and evaluations as "a factual basis for the executive and legislative branches to make appropriate decisions related to the allocation of funds" (OFCM 1997, pp. 3, 25). The plan is now halfway to the fiscal year (FY) 2007 marker set for achieving an 80 percent reduction in fatal accidents, an appropriate time to review progress and consider any needed mid-course corrections.

This mid-course assessment is a periodic review required under the 1997 *National Aviation Weather Program Strategic Plan*.

Beginning with 1996 as the starting point for accident reduction, five years of accident data are now available from the NTSB. These data can be analyzed to determine how much progress has been made toward reducing weather-related accident rates. Throughout this report, *an 80 percent reduction in accidents from the level circa 1996 is used as the benchmark*. This benchmark is used to assess progress and seek areas where more effort, or a redirection of effort, may be worthwhile. This assessment approach amounts to "distributing" the goal of a fivefold reduction in fatal accidents across the three principal regulatory categories for aircraft and across categories for weather-related aviation hazards. Needless to say, the overall national goal can be met without achieving an 80 percent reduction in each category used for analysis. (It may even be preferable, for various reasons, to seek greater reductions in some areas than others.) Still, a consistent yardstick for success provides a convenient and useful starting point for assessing progress and considering mid-course corrective actions.

The remainder of this introduction sets the context for the strategy used in this mid-course assessment and specifies the key assumptions made in the data analysis. Section 2 applies the strategy and assumptions to an analysis of aviation accidents by aircraft regulatory category for the period 1996 through 2001.[1] It provides an overview of total aviation accidents, fatal accidents, and weather-related accidents (total and fatal) for each aircraft category.

Section 3 extends the analysis by differentiating among specific types of weather hazards. This analysis sets the stage for the portfolio analysis in Section 4, which examines how the portfolio of aviation weather programs and initiatives is performing relative to the 2007 goals.

Early in 2001, the OFCM completed a comprehensive analysis of programs and projects that had been identified as meeting the needs and concerns compiled in the *National Aviation Weather Initiatives* report. Programs led by or involving participation of federal agencies, industry, universities, and associations were included. The results of this analysis were presented in the first release (April 2001) of the *National Aviation Weather Initiatives Final Baseline Tier 3/4 Report* (OFCM 2001).[2] A critical source of information for that report was an Aviation Weather User Forum held in July 2000 (OFCM 2000). Since the baseline release, the Tier 3/4 report has become a living document, with ongoing additions of new programs and updates on the status of programs in progress. Section 4 draws on the Tier 3/4 status reviews to provide an overview of all aviation weather programs and to discuss the relevance of specific programs to the results of the hazard analysis. It concludes with highlights of past, current, and future implementations that continue to improve aviation weather safety.

[1]Preliminary 2002 data for some data series were available from the NTSB but were not considered complete enough to include in the analyses in Section 2. Footnotes in Section 2 discuss the effect the 2002 data would have on the trends as presented.

[2]The *National Aviation Weather Program Strategic Plan* (OFCM 1997) constitutes Tier 1. The initiatives set forth in *National Aviation Weather Initiatives* (OFCM 1999) constitute Tier 2.

FAA Accident Reduction Goal and Objectives

Since adopting the 80 percent reduction goal established in the 1998 Safer Skies initiative, the FAA has maintained the following Safety Mission Goal (FAA 2001a, p. 11).

> *By 2007, reduce U.S. aviation fatal accident rates by 80 percent from 1996 levels.*

Under this broad goal are four more-specific objectives (FAA 2001a, pp. 11–12):

- **Fatal Carrier Accident Rate:** By FY 2007, reduce the U.S. commercial air carrier fatal accident rate per 100,000 departures by 80 percent of the 3-year average from FY 1994 to 1996.
- **General Aviation Fatal Accidents:** Reduce general aviation fatal accidents by an amount that will result in a 20 percent improvement of the projected 2007 estimate of 437 (or no more than 350 a year).
- **Overall Aircraft Accident Rate:** Reduce the rate per 100,000 flight-hours.
- **Increase Survivability:** Increase the probability that passengers and crew will survive an air carrier flight.

The FAA assesses year-by-year progress toward these objectives using NTSB accident data, other data sources, and interpretive assumptions.

Although the OFCM mid-course assessment of aviation weather progress is generally consistent with the FAA Safety Mission Goal, the analysis diverges in some details—primarily for technical reasons explained below—from interpretations used by the FAA to chart its progress toward its first three objectives. The first step in presenting these differences is to introduce the shared source of accident data, the NTSB database on aviation accidents.

NTSB Aviation Accident Database

The NTSB uses categories for commercial air carriers and general aviation defined by three parts of the Federal Aviation Regulations (FAR), which constitute Title 14 of the U.S. Code of Federal Regulations:

Part 91 covers all aviation other than military or commercial. In addition to privately owned and operated single- and multiple-engine propeller craft often thought of as general aviation, it includes private company jets, rotorcraft, gliders, balloons, experimental aircraft, aerial

General aviation aircraft regulated under Part 91 include single-engine, propeller-driven craft (left), but also corporate jets. (© AOPA, all rights reserved.) Air taxis and scheduled commercial flights (upper right) that seat fewer than ten passengers are regulated under Part 135, as are other smaller aircraft used in revenue-producing services. (© NATA, all rights reserved.) Part 121 aircraft include both the familiar large airliners (lower right) and smaller craft that can carry at least ten passengers. (Photo courtesy Southwest Airlines.)

application flying (e.g., agricultural aviation), and instructional flying.

Part 121 includes the major passenger airlines and cargo carriers that fly large transport-category aircraft in revenue service. In March 1997, the definition of Part 121 was changed to include all passenger aircraft operated in scheduled revenue service with ten or more seats. Since 1997, therefore, most carriers that are popularly known as commuter airlines are included in Part 121.

Part 135 includes scheduled passenger service in aircraft with fewer than ten seats and nonscheduled operations. The nonscheduled operations refer to revenue-earning flights in which the departure time, departure location, and arrival location are specifically negotiated with the customer or the customer's representative. All cargo flights that come under Part 135 are in the nonscheduled subcategory, as are air taxi services. Private carriage operations with a passenger-seat configuration of 20 seats or fewer and a payload capacity of 6,000 pounds or less come under the nonscheduled Part 135 operations, as do cargo operations in aircraft having a payload capacity of 7,500 pounds or less.

The NTSB reports annual data for Part 121 and the two categories (scheduled and nonscheduled) of Part 135 in the *Annual Review of Aircraft Accident Data for U.S. Air Carrier Operations*. The data for Part 91 are published as a separate series, the *Annual Review of Aircraft Accident Data for U.S. General Aviation*.

Assessment Strategy and Assumptions

For this assessment, OFCM staff obtained NTSB annual accident data for three aviation categories corresponding to Parts 91, 121, and 135. One element of general strategy was to follow FAA practice in working with the data where possible, except where a different approach helps to discern trends or patterns useful in understanding the impact of weather hazards on aviation categories. Another general element, already noted, was to apply the 80 percent reduction goal for 2007 to various subcategories and divisions as a benchmark for assessing weather-related accident trends. These two strategic elements led to the following assumptions.

Separation of Part 121 and Part 135 Aircraft Categories. The FAA combines accident data for Part 121 and the scheduled portion of Part 135 in the data analysis for its first objective (fatal carrier accident rate) and in the commercial portion of the data for its third objective. In effect, the FAA's working definition of "U.S. commercial air carrier" is Part 121 and scheduled Part 135. For several reasons, this report analyzes the Part 121 and scheduled Part 135 data separately (with scheduled Part 135 included with nonscheduled Part 135).

- The analysis of NTSB data showed considerable differences between Part 135 and Part 121 in trends for weather-related accidents.
- Over half of the scheduled Part 135 carriers are licensed for operation in Alaska (NTSB 2002b, p. 25). The weather factors affecting smaller aircraft in Alaskan airspace represent a special case, with special challenges (NRC 1995, Appendix I). Lumping scheduled Part 135 accidents with Part 121 accidents, particularly when focusing on weather factors, would lose important distinctions.
- The available NTSB data on specific weather factors cited in accidents did not distinguish between nonscheduled and scheduled Part 135.

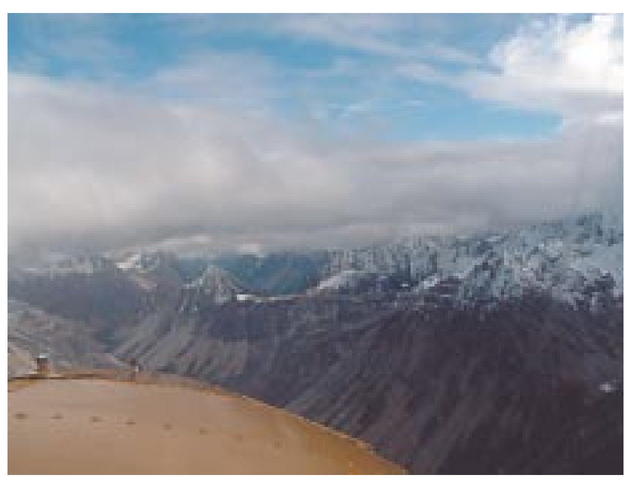
For these reasons, Part 121 data and Part 135 data are maintained as separate aircraft categories throughout this assessment.

Denominator for Computing Accident Rates. Prior to 2001, the FAA used flight-hours as the denominator for computing an accident rate (e.g., accidents per 100,000 flight-hours) for both commercial air carriers and general aviation. Starting with the FAA's 2001 strategic plan, the denominator for commercial air carrier accident rates was changed to departures (accidents per 100,000 departures). The reason given was that "accidents per departure is a more accurate reflection of commercial passenger risk" (FAA 2001b, p. 5). To conform with the FAA's new practice, this report uses accidents per 100,000 departures as the rate statistic for Part 121. Estimates of annual departures were not available for all of Part 135 or for Part 91, so this report uses accidents per 100,000 flight-hours as the rate statistic for those aircraft categories. (The FAA still uses this rate statistic for its general aviation category, which includes Part 91 and nonscheduled Part 135.)

Base for 80 Percent Reduction Goal Computation. To set the 2007 goal for its first safety objective, the FAA averaged the "commercial air carrier" accident rates for 1994, 1995, and 1996. Section 2 of this report also uses the average of data from these three years to compute the base rate for 80 percent reduction goals. Because the latest accident data available in 2007 will be for 2006, this analysis assumes that the reduction goal should be reached in 2006. The reduction goals shown in the figures in Section 2 are 20 percent of the average of the corresponding accident statistic for 1994, 1995, and 1996. They are labeled as 2006 goals, for comparison with trend projections of accident rate data to 2006. For the weather hazard trend analyses in Section 3, 1994 data were not available. Therefore, the 2006 goals in Section 3 are computed at 20 percent of the average of the 1995 and 1996 statistics.

Eighty Percent Reduction Goals for Part 91. The FAA safety improvement goals for general aviation include having no more than 350 fatal accidents per year. The analysis of NTSB Part 91 accident data for this report indicates that *an 80 percent reduction in the weather-related fatal accident rate is within reach*. Furthermore, the *National Aviation Weather Initiatives* report did not restrict the scope of its 80 percent reduction goal to just commercial air carriers. For both reasons, this report assumes an 80 percent reduction goal for Part 91 aviation, calculated on the same base years as the commercial aviation goals for Parts 121 and 135.

Weather-Related Accidents. The NTSB database identifies accidents in which weather is considered a factor, without distinguishing between weather as the principal cause or as a contributing factor. For this assessment, all accidents in which weather was identified as a factor are considered to be weather-related.



Flying over Merrill Pass, Alaska. Mountainous terrain is extremely beautiful, but weather can also make it extremely dangerous. Photo courtesy FAA Capstone program.

2

Overview of Aviation Accident Data 1996–2001

Table 1 contains the source data used for the analyses in this section. Aviation accident data from the NTSB are labeled “Accidents” for Parts 121 or 135 and “Accident-involved aircraft” for Part 91. The departure and flight-hour estimates in the table’s middle column are from the FAA. The accident rate data in the last four columns are derived from these source data. Data are shown for all accidents in an aircraft category, all weather-related accidents, fatal accidents from all causes, and weather-related fatal accidents. As noted earlier, “weather-related” includes all accidents in which weather was identified in the NTSB database as a factor.

The accident counts for Part 91 are counts of aircraft involved in accidents, rather than counts of accidents. This distinction affects the “All” and “Fatal” columns, which include collisions between aircraft. According to the NTSB staff who provided the data, weather-related accidents almost always involve a single aircraft, so the number of aircraft involved can be considered the same as the number of accidents.

The September 11, 2001, terrorist actions substantially reduced the level of activity in all three aircraft categories (compare the estimates of departures and flight-hours for 2001 with the estimates for earlier years). This extreme externality to weather as a factor in aviation accidents illustrates the value in using an accident rate statistic to assess accident reduction progress, rather than accident counts. All of the data series graphed in this report use accident rate data, with a denominator of either departures (for Part 121) or flight-hours (for Parts 135 and 91). Following FAA practice, accidents caused by illegal acts have not been counted in the accident rates in Table 1.

Major Commercial Carriers

Figure 1 displays two data series for Part 121 (major commercial carriers) fatal accidents beginning in 1996. The top series is for all fatal accidents; the lower is for weather-related fatal accidents. In addition to annual rate statistics (accidents per 100,000 departures, from the right-hand columns of Table 1), Figure 1 includes three-year moving average curves for each data series. In these curves, the value for a given year represents the average of the observed values for that year and the two preceding years. The FAA uses only a three-year moving average in its graphs of commercial air carrier fatal accident rates (FAA 2001a, 2001b, 2002a, 2002b). For Part 121, the number of accidents per year is small relative to the variation from year to year, and a moving average curve helps in displaying multiyear trends, particularly changes in trend direction. The three-year moving average curve

Figure 1. Part 121 aviation, fatal accidents per 100,000 departures

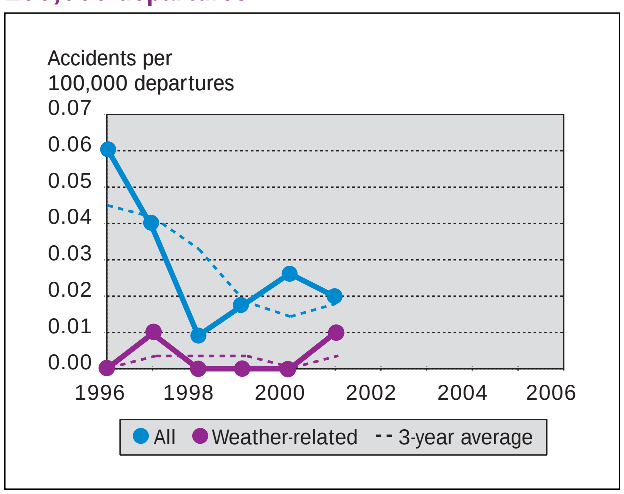


Table 1. Accident data by aircraft regulatory category

Part 121, larger commercial air carriers

Year	Accidents: All	Accidents: Weather-related	Accidents: Fatal	Accidents: Weather-related fatal	Departures	Accidents per 100,000 departures: All	Accidents per 100,000 departures: Weather-related	Accidents per 100,000 departures: Fatal	Accidents per 100,000 departures: Weather-related fatal
1994	23[a]	6	4	0	8,238,306	0.27[a]	0.073	0.049	0.0000
1995	36	10	3	0	8,457,465	0.43	0.118	0.035	0.0000
1996	37	11	5	0	8,228,810	0.45	0.134	0.061	0.0000
1997	49	18	4	1	10,318,383	0.47	0.174	0.039	0.0097
1998	50	9	1	0	10,979,762	0.46	0.082	0.009	0.0000
1999	51	10	2	0	11,308,762	0.45	0.088	0.018	0.0000
2000	56	16	3	0	11,457,812	0.49	0.140	0.026	0.0000
2001	45[a]	10	6[a]	1	10,082,023	0.41[a]	0.099	0.020[a]	0.0099

Part 135, smaller commercial carriers in revenue service

Year	Accidents: All	Accidents: Weather-related	Accidents: Fatal	Accidents: Weather-related fatal	Flight-hours	Accidents per 100,000 flight-hours: All	Accidents per 100,000 flight-hours: Weather-related	Accidents per 100,000 flight-hours: Fatal	Accidents per 100,000 flight-hours: Weather-related fatal
1994	95	31	29	13	5,249,129	1.81	0.59	0.55	0.25
1995	87	25	26	11	5,113,866	1.70	0.49	0.51	0.22
1996	101	29	30	8	5,976,755	1.69	0.49	0.50	0.13
1997	98	30	20	9	4,080,764	2.40	0.74	0.49	0.22
1998	85	26	17	7	4,155,670	2.05	0.63	0.41	0.17
1999	86	25	17	5	3,640,731	2.36	0.69	0.47	0.14
2000	92	28	23	9	3,922,535	2.35	0.71	0.59	0.23
2001	79	18	20	6	3,476,432	2.27	0.52	0.58	0.17

Part 91, general aviation[b]

Year	Accident-involved aircraft: All	Accident-involved aircraft: Weather-related	Accident-involved aircraft: Fatal	Accident-involved aircraft: Weather-related fatal	Flight-hours	Accident-involved aircraft per 100,000 flight-hours: All	Accident-involved aircraft per 100,000 flight-hours: Weather-related	Accident-involved aircraft per 100,000 flight-hours: Fatal	Accident-involved aircraft per 100,000 flight-hours: Weather-related fatal
1994	2,022	344	404	87	22,235,000	9.09	1.55	1.82	0.39
1995	2,056	426	413	109	24,906,000	8.26	1.71	1.66	0.44
1996	1,908	442	361	109	24,881,000	7.67	1.78	1.45	0.44
1997	1,845	383	350	87	25,591,000	7.21	1.50	1.37	0.34
1998	1,904	370	364	91	25,518,000	7.46	1.45	1.43	0.36
1999	1,906	357	340	65	29,713,000	6.41	1.20	1.14	0.22
2000	1,837	356	344	85	29,057,000	6.32	1.23	1.18	0.29
2001	1,726	280	325	38	27,451,000	6.29	1.02	1.18	0.14

All accident data are from the NTSB. Flight-hour and departure estimates are from the FAA.

[a]For 1994, accident count includes one nonfatal accident due to an illegal act. For 2001, count includes four fatal accidents due to the September 11, 2001, terrorist acts. Following FAA practice, these accidents are excluded from the accident rate computations (accidents per 100,000 departures).

[b]Data for Part 91 aircraft are for numbers of accident-involved aircraft rather than numbers of accidents.

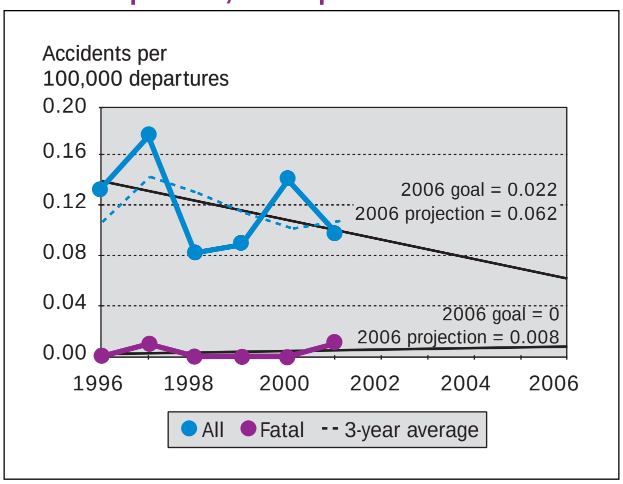
for the top series differs somewhat from the curve used in the FAA's strategic plans because the FAA includes scheduled Part 135 data in its calculation.

During the six years represented in this graph, there were only two weather-related fatal accidents involving Part 121 aircraft. This small number of occurrences prevents a useful statistical analysis of the trend over this duration. As a surrogate indicator for the trend in fatal accidents, one may look for the trend in all weather-related accidents, which are more frequent. Figure 2 shows that this trend (top data series) is in fact downward. In addition to the three-year moving average used by the FAA (dashed curves), Figure 2 shows the straight-line regressions calculated for the underlying annual accident rates in each data series.

For this assessment, a straight-line regression has the advantage of providing a forward projection to an "expected" value in the goal year of 2006—assuming that the trend in observations to date continues. In Figure 2, goals for 2006 for both data series were calculated as 20 percent of the average accident rates for 1994 through 1996. The projected value of the linear trend for 2006 (or zero, if the linear trend reaches the x axis before 2006) is given as the 2006 projection for the data series.

Using all accidents as an indicator of the trend in weather-related fatal accidents, achieving an 80 percent reduction by 2006 for Part 121 aviation will require more improvement than occurred from 1996 through 2001. However, the variability in the annual accident rate is a reminder that a simple linear projection may prove unreliable.[1] The weather factor analysis in Section 3 will identify specific areas of concern where efforts should be focused to meet the 80 percent reduction goal for the major commercial air carriers.

FIGURE 2. Part 121 aviation, weather-related accidents per 100,000 departures



Smaller Aircraft in Revenue Service

Figures 3 and 4 show data series for Part 135 (smaller aircraft in revenue service) analogous to those shown in Figures 1 and 2 for Part 121. As noted in the discussion of assumptions, estimates of annual departures for non-scheduled Part 135 aviation were not available, so the rates shown are accidents per 100,000 flight-hours. In Figure 3, the linear regression line for weather-related fatal accidents suggests an increasing trend. The projected 2006 value of 0.218 accidents per 100,000 flight-hours is well above the goal of 0.040 accidents per 100,000 flight-hours. The data series for all weather-related accidents (Figure 4, top series) shows a similar upward trend, despite a high year-to-year variability. The general impression one can take from these data is that the smaller commercial air carriers that fall under FAR Part 135 are not yet experiencing substantial reductions in weather-related accident rates consistent with the goal set by the NAW/PC.[2] This impression will be strengthened in Section 3, when we examine how specific weather hazards are affecting Part 135 accident rates.

FIGURE 3. Part 135 aviation, fatal accidents per 100,000 flight-hours

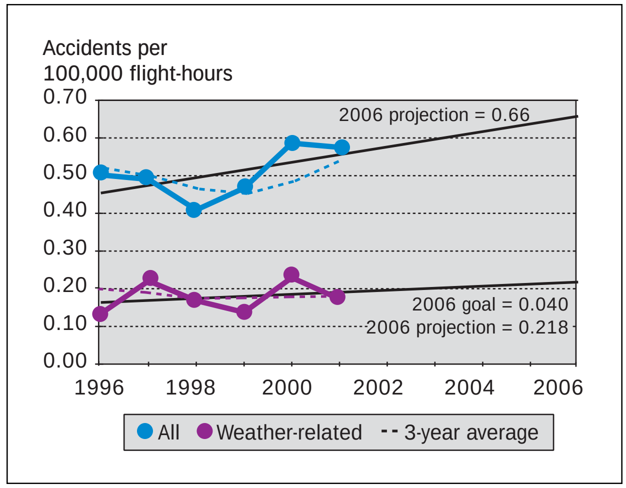
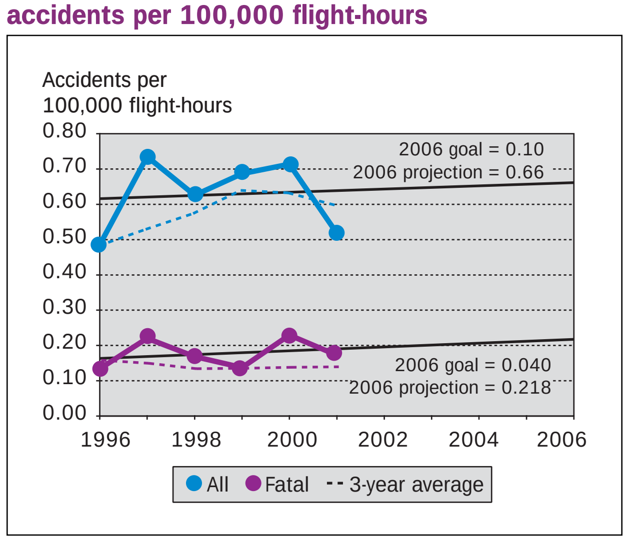


FIGURE 4. Part 135 aviation, weather-related accidents per 100,000 flight-hours



[1] The preliminary NTSB accident data for Part 121 in 2002 show two weather-related accidents (0.019 accidents per 100,000 departures) and no fatal weather-related accidents. If these numbers are confirmed, the trend for all weather-related Part 121 accidents approaches zero before 2006.

[2] The preliminary NTSB data for Part 135 in 2002 show three weather-related accidents (0.09 per 100,000 flight-hours), of which one was fatal (0.03 per 100,000 flight-hours). If these early data are confirmed, the Part 135 trends are downward rather than upward, but they still fail to achieve the 80 percent reduction goals.

General Aviation

If the trends in Part 135 aviation accident rates are disappointing with respect to meeting reduction goals, general aviation as defined by FAR Part 91 offers a far brighter prospect. Figures 5 and 6 show the data series comparable to those discussed already for Parts 121 and 135. The numbers of accidents per year are larger for this category, and the data series show substantially less variability around the linear trends than do the data series for Parts 121 and 135. But the truly good news is the strong downward trend in both series shown in Figure 6:

Figure 5. Part 91 aviation, fatal accidents, aircraft per 100,000 flight-hours

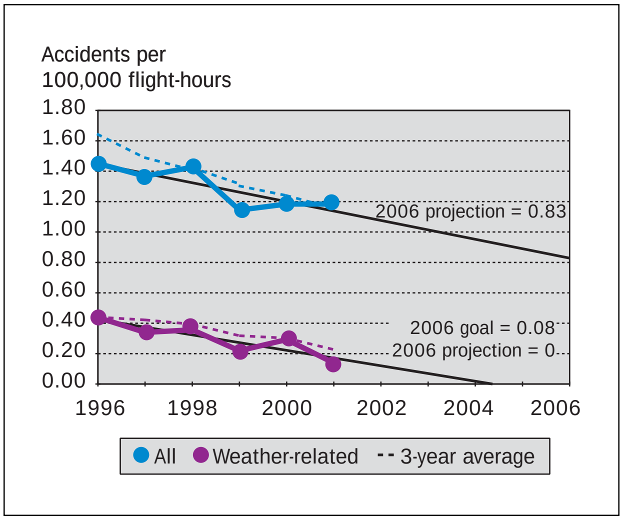
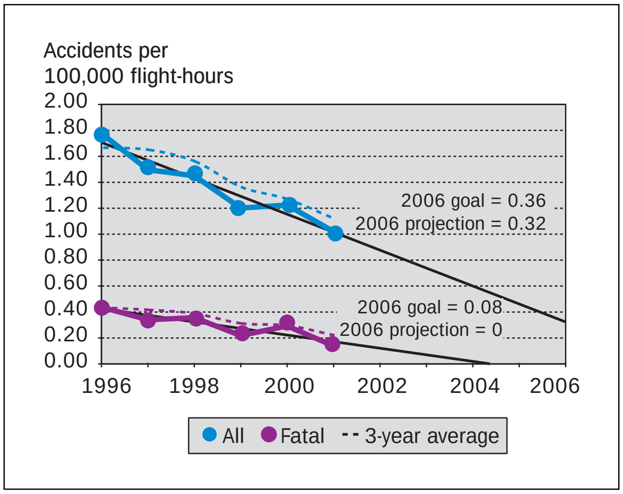


Figure 6. Part 91 aviation, weather-related accidents per 100,000 flight-hours



the rates for all weather-related accidents and for weather-related fatal accidents. If the trends can be sustained, the annual rate for weather-related fatal accidents could be brought well below the goal of 0.08 accidents per 100,000 flight-hours—a goal that is already far more ambitious than the 20 percent reduction goal adopted by the FAA for all general aviation accidents. The weather hazard analysis in Section 3 and the portfolio analysis in Section 4 will help identify factors that appear to have contributed to this success story and highlight the efforts that should be sustained and extended to ensure that the downward trends continue.

3

Risk Analysis for Aviation Weather Hazards

This section extends the analysis of NTSB accident data to examine trends in the frequency with which different kinds of weather hazards have been contributing to aviation accidents since 1995. The accident records in the NTSB database derive from entries in a form completed by an NTSB investigator for each accident. If weather was a possible cause or contributing factor, the form provides a fixed list of choices to describe what conditions were involved. This set of *weather factors* available for selection by an investigator appears to have remained relatively stable since 1995, the first year for which OFCM staff obtained data on the frequency with which weather factors were cited in the NTSB accident records.

Several caveats about the weather factor citation data must be borne in mind. First, an investigator may select more than one factor from the list. The count of citations for a given year will thus exceed the count of corresponding accidents (either all weather-related or weather-related fatal) in that year. Second, a number of the factors overlap, and there is no guarantee that different investigators (or even the same investigator over time) use the same criteria in deciding which factor(s) best describe similar weather situations. Third, as the data on weather-related accidents in a given year are divided into smaller categories, the numbers of accidents per year—and particularly the number of fatal accidents—often becomes small. The reliability of any statistical measure of central tendency, which is essential for an objective analysis of trends, decreases correspondingly. Despite these limitations, the analysis provides useful insights into the weather factors that have been involved in the accidents characterized at a broad level in Section 2.

Service Areas and Weather Hazard Categories

Beginning with the *National Aviation Weather Initiatives* report in 1999, the OFCM and the coordinating structure for aviation weather programs and initiatives have used service areas to characterize initiatives and projects. A *service area* focuses on "meteorological conditions which have either proven to be frequent causes of aviation accidents, injuries, and delays or, in the case of volcanic ash and other airborne hazardous materials, are considered to be serious potential causes" (OFCM 1999). The service areas, numbered as in other OFCM reports, are:

1. Ceiling and visibility
2. Convective hazards
3. En route winds and temperatures
4. Ground de-icing
5. In-flight icing
6. Terminal winds and temperatures
7. Turbulence
8. Volcanic ash and other airborne hazardous materials

The columns in Table 2 show how the weather factors cited in the NTSB data for 1995–2001 are distributed among these service areas, plus a ninth category of "Other" for factors that could not be assigned to an existing service area. (There were no NTSB weather factors identified for either ground de-icing or volcanic ash and other airborne hazardous materials; thus, these two service areas are not included in the table.) The groupings of weather factors within a column and across columns suggest the problems encountered if the service areas are used as the basis for identifying weather hazard trends.

Table 2. Weather factors by service area and hazard category

	Service area					
Hazard category	1. Ceiling & visibility	2. Convective hazards	3. En route winds & temps	5. In-flight icing	6. Terminal winds & temps	7. Turbulence	9. Other
A. Restricted visibility and ceiling hazards	Obscuration Clouds Fog Haze/smoke Low ceiling Whiteout Below approach/landing minimums						
B. Precipitation (non-icing) hazards	Rain Drizzle/mist Snow						
C. Icing conditions				Icing conditions Ice fog Freezing rain			Carburetor icing conditions
D. Turbulence and convection hazards		Thunderstorm Thunderstorm (outflow) Turbulence (thunderstorms) Turbulence, convection induced Microburst/dry Microburst/wet Updraft Downdraft			Gusts Wind shear Dust devil/whirlwind Sudden wind shift Variable wind	Mountain wave Turbulence Turbulence, clear air Turbulence in clouds Turbulence (terrain induced)	
E. Temperature and lift hazards			Temperature inversion		High density altitude Temperature, high Temperature, low		Thermal lift No thermal lift
F. En route and terminal winds			Unfavorable wind		Crosswind High wind Tail wind		
G. Electrical hazards		Lightning					Static discharge
H. Airborne solids hazards	Sand/dust storm	Hail					

In particular, weather factors related to turbulence are spread among three service areas: convective hazards, terminal winds and temperatures, and turbulence.[1] The terminal winds and temperatures service area includes temperature-related factors and factors related to steady horizontal wind conditions, as well as air movements that, from a weather safety perspective, can be characterized as turbulence phenomena. When working with data series consisting of small numbers of observations, grouping like factors together in the same analysis category increases the clarity and strength with which trends emerge.

Rather than changing the definitions of the service areas, which continue to be useful for broader program analysis and planning, this hazard assessment groups related weather factors together as a *weather hazard category*. These hazard categories are shown by the row groupings in Table 2. Table 3 shows the number of times each weather factor is cited in the NTSB database for the period 1995–2001. Yearly citations by weather factor and hazard category are tabulated in Appendix A. The hazard analyses in the remainder of this section use the weather hazard categories. In Section 4, the relationship between hazard categories and the aviation weather service areas, shown in Table 2, is used to link conclusions from the hazard analysis back to service area initiatives and projects.

General Aviation Weather Hazard Trends

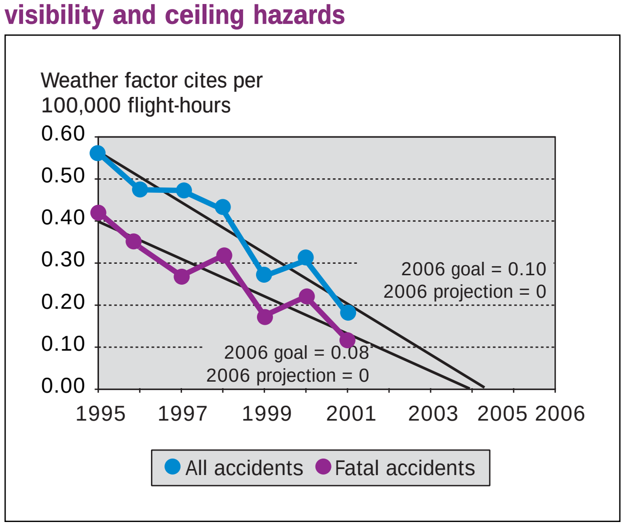
This presentation of weather hazard trends starts with the Part 91 weather-related accidents because the data set is larger. It thus provides a clearer picture of the trends. After the trends for Part 91 aviation are identified, it will be easier to draw comparisons with the sparser data sets for Part 121 and Part 135 weather-related accidents. (Compare the total citations, by aircraft regulatory category, for all weather hazard categories, given at the bottom of Table 3.)

Figures 7 through 12 plot the data series of annual citation frequency for weather factors, using weather hazard categories A through F (as labeled in Tables 2 and 3). Each figure shows two data series: the citation frequency per 100,000 flight-hours for *all* weather-related accidents and the citation frequency for *fatal* weather-related accidents. Linear regressions are plotted for each data series to project the trend to 2006 (or to the x axis, indicating that the trend approaches zero citations per 100,000 flight-hours before 2006). As explained in Section 1, a 2006 goal is calculated for each data series as 20 percent of the average citation frequency for 1995 and 1996. Weather hazard categories G through I are not plotted because the citations per year are too few to provide useful trend analysis. Tables A-1 and A-2 in Appendix A contain the citation frequency values from which Figures 7 through 12 were plotted.

Figure 7, for Category A, shows that the citation rates for both data series trend strongly toward zero before 2006. Furthermore, the data fall close to the trend lines. The Category A totals in Table 3 show that these hazards have in the past been a major contributor to Part 91 weather-related accidents (as well as Part 135 accidents). This steep decline in citation rates is an important contributor to the overall trends for Part 91 described in Section 2. The data for Category C, icing conditions, in Figure 9 also show strong downward trends for both data series.

The trends for Category B, non-icing precipitation hazards (Figure 8) and Category D, turbulence and convection hazards (Figure 10) also show downward trends for which the 80 percent reduction goals for fatal weather-related accidents are met before 2006. However, the

Figure 7. Part 91, trend for Category A, restricted visibility and ceiling hazards



[1]The term “turbulence” as used in this report corresponds to *aircraft turbulence*, defined by the American Meteorological Society Glossary of Meteorology as “irregular motion of an aircraft in flight, especially when characterized by a rapid up-and-down motion, caused by a rapid variation of atmospheric wind velocities.”

trends for all weather-related accidents come close to the desired 2006 benchmark, even exceeding it slightly in the case of non-icing precipitation hazards. These two categories will bear watching for Parts 121 and 135.

Table 3. Weather factor contributions to hazard category citation frequency, 1995–2001

		Citations, all weather accidents			Citations, fatal weather accidents		
Hazard category	Weather factor	Pt. 91	Pt. 135	Pt. 121	Pt. 91	Pt. 135	Pt. 121
A. Restricted visibility and ceiling hazards	Obscuration	56	6		43	3	
	Clouds	103	12		65	10	
	Fog	203	28	1	143	12	0
	Haze/smoke	26			11		
	Low ceiling	286	47	1	213	26	0
	Whiteout	8	17	1	1	4	0
	Below approach/ landing minimums	24	1		11	0	
	Category total	706	111	3	487	55	0
B. Precipitation (non-icing) hazards	Rain	60	8	2	35	3	0
	Drizzle/mist	18	2	1	13	1	0
	Snow	75	16	1	47	6	0
	Category total	153	26	4	95	10	0
C. Icing conditions	Icing conditions	88	23	1	44	11	0
	Ice fog	1			1		
	Freezing rain	7	3		4	0	
	Carburetor icing conditions	148	3		10	0	
	Category total	244	29	1	59	11	0
D. Turbulence and convection hazards	Thunderstorm	46	1		33	0	
	Thunderstorm (outflow)	7			1		
	Turbulence (thunderstorms)	12	1	7	10	1	0
	Turbulence, convection induced			2			0
	Microburst/dry	4			0		
	Microburst/wet	1			1		
	Updraft	4			0		
	Downdraft	135	13		12	2	
	Gusts	528	16	1	38	1	0
	Wind shear	46		2	7		0
	Dust devil/whirlwind	30			1		
	Sudden wind shift	61			2		
	Variable wind	62	3		1	0	
	Mountain wave	10		1	6		0
	Turbulence	59	3	24	21	0	0
	Turbulence, clear air	7		24	2		1
	Turbulence in clouds	7	1	10	5	1	0
	Turbulence (terrain induced)	29	5		14	2	
	Category total	1,048	43	71	154	7	1
E. Temperature and lift hazards	Temperature inversion	1			0		
	High density altitude	223	10		47	2	
	Temperature, high	15		2	1		1
	Temperature, low	4	1		1	1	
	Thermal lift	5			0		
	No thermal lift	23			2		
	Category total	271	11	2	51	3	1
F. En route and terminal winds	Unfavorable wind	72	6	2	5	0	0
	Crosswind	646	21	4	14	0	0
	High wind	136	8		22	4	
	Tail wind	307	18		33	1	
	Category total	1,161	53	6	74	5	0
G. Electrical hazards	Lightning	3	1		3	0	
	Static discharge	1			1		
	Category total	4	1	0	4	0	0
H. Airborne solids	Sand/dust storm	1			1		
	Hail	3		1	2		0
	Category total	4	0	1	3	0	0
I. Not specified			1	2			0
Total, all weather hazard categories		3,591	275	90	927	91	2

Figure 8. Part 91, trend for Category B, precipitation (non-icing) hazards

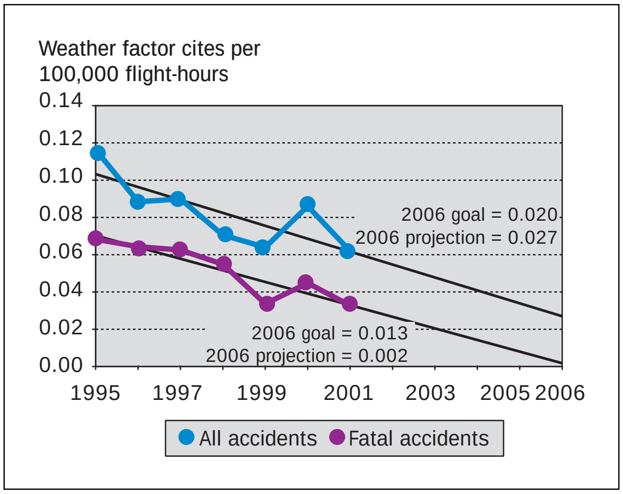


Figure 9. Part 91, trend for Category C, icing conditions

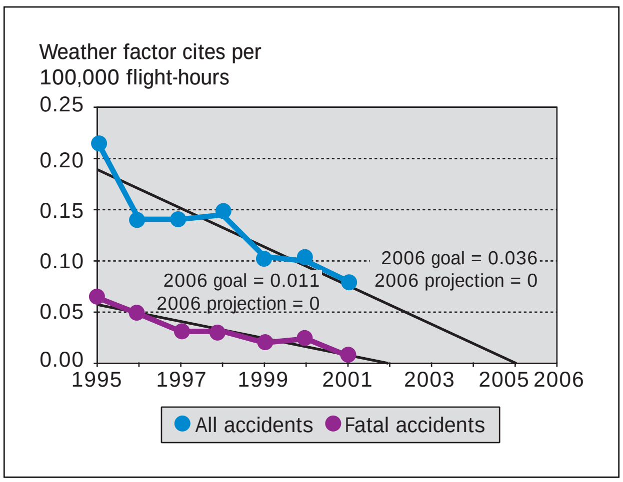


Figure 10. Part 91, trend for Category D, turbulence and convection hazards

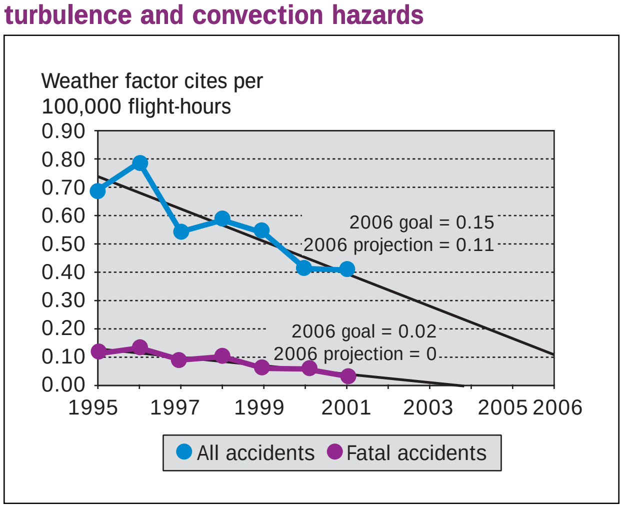
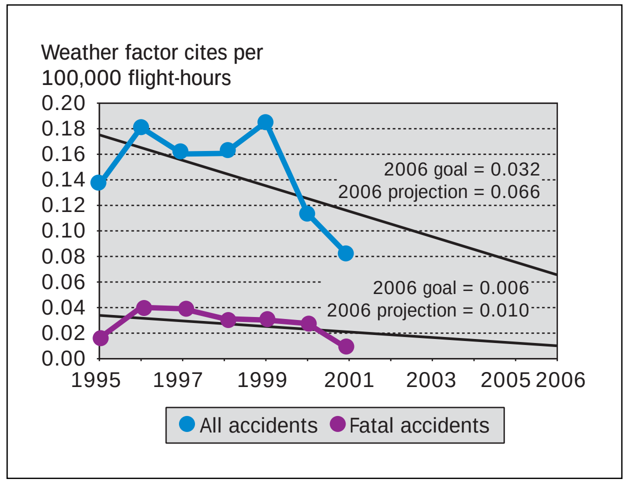


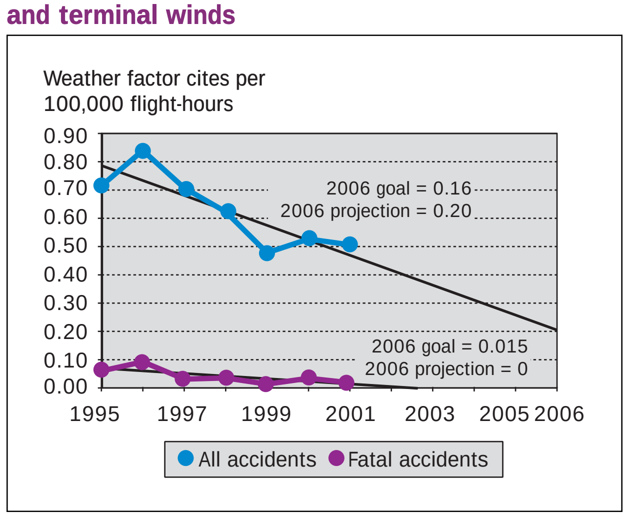
Figure 11 contains the data series for Category E, temperature and lift hazards. A noteworthy feature of the citation data for Category E is that 80 percent of the citations for all weather-related accidents and 90 percent of citations for weather-related fatal accidents are for high density altitude (see Table 3). The citations for this factor are distributed across the time period (see Appendix A) and dominate the shape of the data series graphs. Attention to this specific weather factor could make a significant difference in reducing accident rates in this weather hazard category. The trend lines in Figure 11 indicate that 80 percent reductions in this area are unlikely to be achieved without addressing the high density altitude problem.

Figure 11. Part 91, trend for Category E, temperature and lift hazards



Category F (Figure 12) is another interesting case. This category had the most citations for all accidents of any

Figure 12. Part 91, trend for Category F, en route and terminal winds



category, but fewer citations for fatal accidents than several others. The fatal accident trend in Figure 12 indicates that an 80 percent reduction is feasible by 2006, but the slope of the downward trend depends on a high value in 1996 and a low value in 2001. The data series for all weather-related accidents trends to just above the 80 percent reduction goal. This weather hazard category is another to keep in mind when examining the Part 121 and 135 data.

Part 121 Weather Hazard Trends

Weather-related fatal accidents in Part 121 aviation are too infrequent to provide adequate data for trend analysis. As Table 3 shows, there were just two weather factor citations for fatal accidents in the 1995–2001 period, one for turbulence, the other for high temperature. Table 4 shows the weather factor citations, aggregated by weather hazard categories, during this period for all weather-related accidents. These data series will serve as surrogate indicators of trends for the Part 121 aircraft category. (Complete Part 121 data are in Appendix A.)

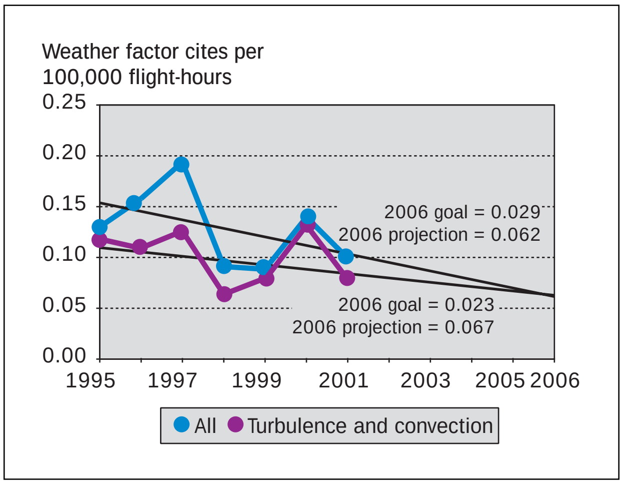
The most notable feature in the data is the prominence of Category D, turbulence and convection hazards, in the citations each year. Category D is just one among several weather hazard categories that contribute substantially to the citation totals for general aviation. But these turbulence and convection hazards dominate the weather conditions that continue to contribute to accidents—albeit not usually fatal ones—for the major air carriers.

Table 4. Part 121 weather factor citations, all accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001
All factors	11	13	20	10	10	16	10
Frequency per 100,000 departures	0.130	0.158	0.194	0.091	0.088	0.140	0.099
A. Restricted visibility and ceiling hazards							
Fog		1					
Low ceiling							1
Whiteout			1				
Total category citations	0	1	1	0	0	0	1
B. Precipitation (non-icing) hazards							
Rain		1	1				
Snow			1				
Drizzle/mist				1			
Total category citations	0	1	2	1	0	0	0
C. Icing conditions							
Icing conditions			1				
Total category citations	0	0	1	0	0	0	0
D. Turbulence and convection hazards							
Turbulence (thunderstorms)		1	1	3			2
Turbulence, convection induced						1	1
Gusts						1	
Wind shear	1					1	
Mountain wave						1	
Turbulence	5	1	3	1	5	6	3
Turbulence, clear air	3	7	7	2	3	2	
Turbulence in clouds	1		2	1	1	3	2
Total category citations	10	9	13	7	9	15	8
Frequency per 100,000 departures	0.118	0.109	0.126	0.064	0.080	0.131	0.079
E. Temperature and lift hazards							
Temperature, high		1					1
Total category citations	0	1	0	0	0	0	1
F. En route and terminal winds							
Unfavorable wind	1			1			
Crosswind		1	2			1	
Total category citations	1	1	2	1	0	1	0
H. Airborne solids hazards							
Hail				1			
Total category citations	0	0	0	1	0	0	0
I. Other			1		1		
Total category citations	0	0	1	0	1	0	0

Figure 13 graphs the data series for the Part 121 citation rates (per 100,000 departures) for all weather factors and for Category D. If these trends were to hold, by 2006 Category D would be responsible for virtually all the Part 121 weather-related accidents. In addition—and more significant for this mid-course assessment—the trend for all weather-related accident citations does not project to the desired 2006 goal. Category D is clearly the chief obstacle to greater progress.

Figure 13. Part 121, trends for all weather hazards and for turbulence and convection hazards



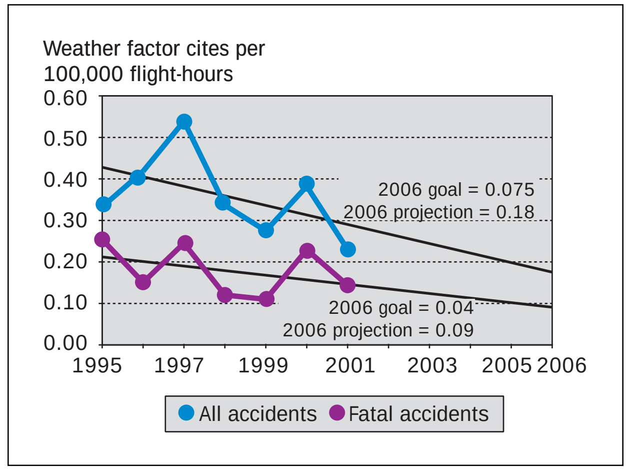
Part 135 Weather Hazard Trends

Figures 14 through 19 plot the data series for Part 135 aviation accidents corresponding to those in Figures 7 through 12 for Part 91. The yearly weather factor citation data from which the citation rate graphs derive are in Appendix A, Tables A-5 and A-6.

Comparisons of Part 135 and Part 91 by weather hazard category are valuable for two reasons. First, the aircraft types, flight durations and conditions, and airport facilities of Part 91 and Part 135 aviation are arguably more similar to each other than either is to Part 121 aviation. As noted in Section 1, the FAA often compiles data on nonscheduled Part 135 aviation with Part 91 data to create a "general aviation" category. The small propeller-driven or turboprop craft that still fall within the scheduled Part 135 category after the 1997 change to the FAR fly from and to airports, and at in-flight altitudes, more typical of general aviation than of the larger Part 121 aircraft. Second, given these basic similarities, differences between Part 135 and Part 91 in trends for the same weather hazard category suggest that factors specific to Part 135 may need to be identified and addressed if accident reduction goals are to be achieved.

Figure 14, compared with Figure 7, shows that Part 135 aviation is not experiencing the same improvement in risk of restricted visibility and ceiling hazards that holds

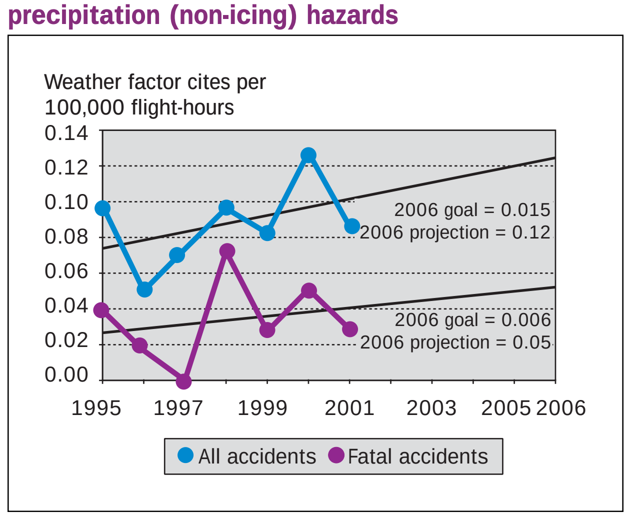
Figure 14. Part 135, trend for Category A, restricted visibility and ceiling hazards



for general aviation (Part 91). Whereas Part 91 is on a course to reach and exceed an 80 percent reduction in the Category A citation rate for all accidents and for fatal accidents well before 2006, neither data series for Part 135 is on a trend to achieve this goal by 2006.

The comparison between Figure 15 and Figure 8 for Category B is even more startling. Of course, the variability in the Part 135 data, which reflects the small numbers of non-icing precipitation citations per year, increases the

Figure 15. Part 135, trend for Category B, precipitation (non-icing) hazards



uncertainty about the trends. But the fact that both trends are on upward paths cannot be ignored, particularly when they are compared with the distinct downward trends for the Part 91 data series in Figure 8. The same pattern appears for Category C, icing conditions (Figure 16 for Part 135; Figure 9 for Part 91).

The first good news for Part 135 comes in Category D, turbulence and convection hazards (Figure 17 for Part 135, Figure 10 for Part 91). If the trend in citations for fatal accidents holds, this category of weather hazards will approach a zero rate for Part 135 even earlier than it will for Part 91. However, the citation trend for all weather-related accidents does not confirm the favorable trend. Turbulence should be viewed as a continuing issue for Part 135, just as it is for Parts 91 and 121.

For the two remaining weather hazard categories, temperature and lift hazards and en route and terminal winds, there is considerable inter-year variability in the data series (Figures 18 and 19, respectively). The data series for citations in fatal accidents have downward trends. But unlike the counterpart data series for Part 91 (Figures 11 and 12), the data for all weather-related accidents do not corroborate these indications of improvement.

Figure 16. Part 135, trend for Category C, icing conditions

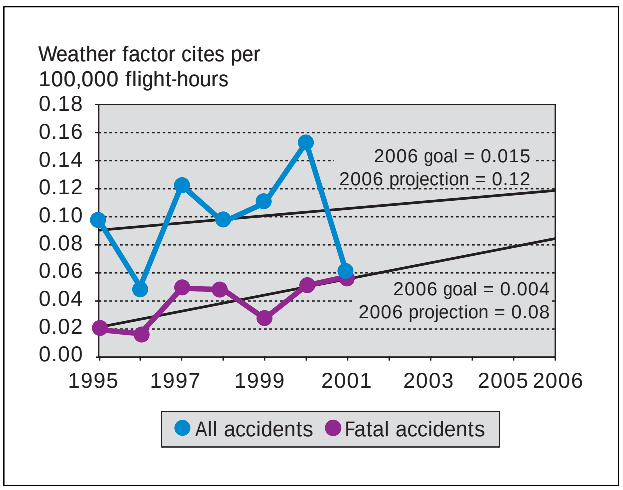


Figure 17. Part 135, trend for Category D, turbulence and convection hazards

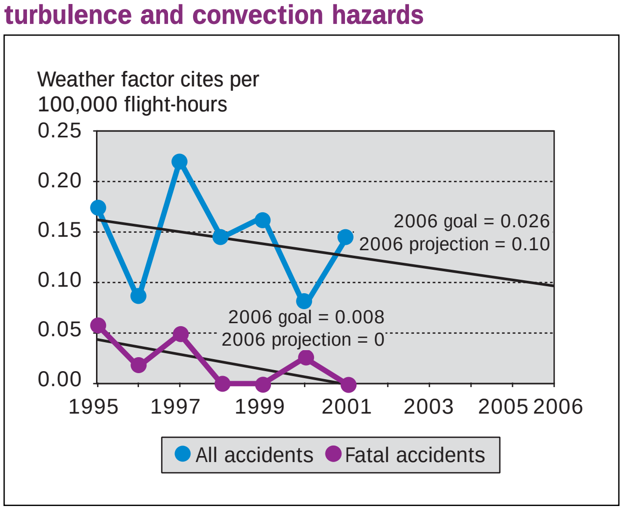


Figure 18. Part 135, trend for Category E, temperature and lift hazards

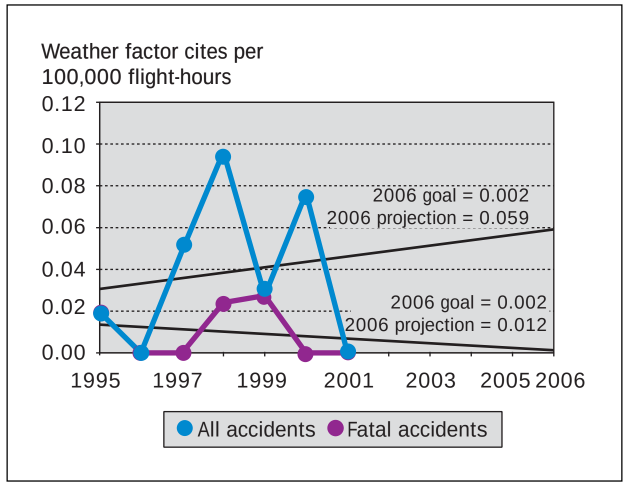
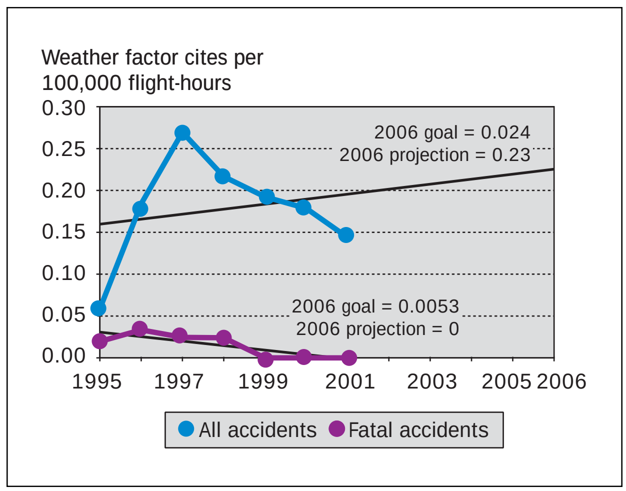


Figure 19. Part 135, trend for Category F, en route and terminal winds



Conclusions from the Weather Hazard Risk Analysis

The following conclusions, drawn from the data analyses described in Sections 2 and 3, provide the basis for the first part of the program portfolio analysis in Section 4.

1. Weather-related accidents involving Part 91 aircraft, particularly fatal accidents, have been decreasing over the period analyzed. Something has, or *some things* have, been going right for general aviation with re-

spect to decreasing weather-related accidents since 1996. If programs that have been implemented or extended within the past 7 to 10 years can be identified as contributing to these improvements, ways to further extend their reach into the aviation community should be promoted.

2. The aircraft category regulated under FAR Part 135 displays weather-related accident rate trends distinct from both the Part 91 and Part 121 categories. Aviation weather initiatives and programs should consider special factors relevant to this category, rather than assuming it is partly like the large commercial air carriers and partly like general aviation.

3. Weather-related fatal accidents in the Part 121 aircraft category are becoming rare events. This risk analysis has had to turn to trends in all weather-related accidents as a surrogate statistical indicator for major air carriers. Using this indicator, turbulence and convection hazards constitute the weather hazard category that contributes most often to Part 121 accidents. These weather phenomena continue to be problematic for Part 91 and Part 135 aircraft as well. The aviation weather program portfolio should have a balanced range of projects in the pipeline that can be expected to help reduce the impact of these hazards.

4. High density altitude is the factor within the temperature and lift hazards category that is most frequently cited in accidents for both Part 91 and Part 135 aviation. Although single factors in other categories are cited more often, this particular factor deserves attention in the aviation weather program portfolio.

5. The annual statistics on weather factor citations in Appendix A show that a number of other factors in different weather hazard categories continue to be cited in multiple accidents each year, particularly for Part 91 aircraft. Although the frequency of citations is generally declining over the analysis period, sustaining the downward trends until reduction goals are met will require continued support for programs and initiatives that address these factors. Examples of such factors are fog and low ceiling in Category A, restricted visibility and ceiling hazards; gusts in Category D, turbulence and convection hazards; and crosswinds and tail winds in Category F, en route and terminal winds.

4

Aviation Weather Programs—Portfolio Analysis

Portfolio Overview

As noted in the Introduction, the *National Aviation Weather Initiatives Final Baseline Tier 3/4 Report* (OFCM 2001) and the Aviation Weather User Forum (OFCM 2000) were initial efforts in a continuing OFCM analysis and status review of a national portfolio of aviation weather initiatives and programs. A new feature of the continuing Tier 3/4 analysis is a categorization of every program according to the type of benefit users would get from it; that is, the principal product or service. The five categories, which originated in the 2000 Aviation Weather User Forum, are:

- Weather product development (e.g., weather observation and/or forecast systems or system products)
- Weather product dissemination (e.g., systems or services that deliver weather products to end users)
- Education, training, and outreach (informing current and potential users about available weather products and how to use those products effectively)
- Cockpit displays (e.g., hardware/software systems to present current weather information to the in-flight pilot in real time)
- Decision support systems and capabilities (systems that help users interpret weather information using procedures, operational concepts, and regulations)

A series of tables (Tables 5 through 11) are presented at the end of this section to provide, at a summary level, an update and extension of the April 2001 Tier 3/4 release, drawing on the information being gathered for the next release. Tables 5 through 8 relate the programs led by federal agencies to the five program product categories listed above (table columns) and the eight aviation weather initiative service areas (table rows). Table 9 does the same for the aviation weather programs and projects led by universities, industry, or trade associations. The acronyms used in Tables 5 through 9 are explained in Table 10, which includes a brief description of the major results (benefit to users) of each program, as well as the lead and partnering entities. Tables 5 through 9 are color-coded to indicate whether the major product has already been implemented (implementation in FY 1997–2002), is in implementation now (FY 2003–04), or is expected to be implemented later in the ten-year program assessment period (FY 2005–07). This same information is indicated by a letter code in the "Status" column of Table 10. Many of the education and training programs listed in Table 10 have produced multiple courses or training modules. These are listed in Table 11. In the portfolio analysis below, program acronyms as given in Table 10 are highlighted in boldface.

Programs Relevant to the Hazard Analysis

This section looks at the aviation weather program portfolio in light of the five conclusions from the end of Section 3 on reducing the risk of weather-related aviation accidents. The intent is to draw out implications of those conclusions for managing the portfolio in the future.

Risk Reduction Success in General Aviation

Explaining the strong downward trends in Part 91 aviation accidents described in Sections 2 and 3 is at this point largely an exercise in conjecture. The downward trend is evident in all weather hazard categories, with the possible exception of Category E, temperature and lift hazards, and across all service areas. However, the

OFCM staff has accumulated enough anecdotal information and objective metrics to promote one conjecture to the status of a reasonable hypothesis for continued exploration. According to this hypothesis, the trends in accident reduction are largely due to an effective combination of multiple factors:

- Beginning in the 1990s and continuing through the present, the National Weather Service Modernization has produced a revolution in weather information products from Doppler weather radar, satellite imagery, improved numerical weather prediction models, and product dissemination systems. Many of these advances have improved the reliability and utility (e.g., finer scale observational and forecast data) of weather information products to aviation users—provided they get the information in useful form and within the time frames of their decision processes.
- Aviation-specific systems and products supported by the FAA, such as Terminal Doppler Weather Radar (**TDWR**), the Medium Intensity Airport Weather System (**MIAWS**), and the Weather System Processor (**WSP**) have increased the ability of air traffic controllers, traffic flow managers, and flight service station specialists to help the general aviation pilot avoid weather hazards during departure and landing.
- Information communication systems and weather product dissemination systems have made it easier for general aviation pilots to access the information available in improved weather products, particularly for preflight planning and in-flight decision making to avoid weather hazards. Public-private partnering and for-profit ventures have given general aviation pilots a range of affordable, practical, and reliable channels for information.
- Through education and training courses, large numbers of general aviation pilots have learned to use the information available to them to avoid hazardous weather conditions.

The last of these factors, education and training for the general aviation pilot, is the linchpin that ties together the first three factors, which provide the technology and service basis, into a success story.

The web page for ADDS, a product of interagency partnering, has become a favorite information source for general aviation pilots planning their next flight. ADDS provides current versions of weather maps and other products. Image courtesy NOAA/AWC.

The evidence for this explanation includes discussions OFCM staff members have had with representatives of the general aviation community, such as staff from the Aircraft Owners and Pilots Association (AOPA), supported by use statistics for education/training offerings and aviation weather dissemination systems. AOPA staff involved with aviation weather information for the general aviation community cited the following factors (AOPA 2003):

Pilot Education. Training programs (seminars and course offerings) have likely been a major contributing factor. Statistics are presented below on numbers of participants in some of the programs listed in Table 11.

Improved Availability and Quality of Aviation Weather–Related Information. Sources such as The Weather Channel®, which disseminates and interprets weather data and information from the National Oceanic and Atmospheric Administration (NOAA), and the Internet have significantly improved the quality, timeliness, and accuracy of weather information available to general aviation pilots. The Aviation Digital Data Service (**ADDS**), an Internet-based weather product dissemination service, has been widely used and accepted by the general aviation community. ADDS is funded by the FAA Aviation Weather Research Program (AWRP), with development and maintenance support from the National Center for Atmospheric Research (NCAR) and from NOAA's Forecast Systems Laboratory (FSL) and Aviation Weather Center (AWC). Data on ADDS user access are presented later in this section with the highlights of weather product dissemination programs.

More Use of Flight Services Briefings. Following the September 11, 2001, terrorist attacks using hijacked aircraft, aviation industry associations have been stressing to their members that pilots must pay attention to notices to airmen (NOTAMs) and receive a preflight briefing. As a result, general aviation pilots are calling flight information services more frequently. Along with NOTAMs for the pilot's route, the flight information services typically provide aviation routine weather reports (METARs), pilot reports (PIREPs), and other weather information.

Use of New Datalink Technologies for Weather Information in the Cockpit. The use of datalink technologies to obtain real-time graphical weather information (e.g., radar imagery) in the cockpit is just beginning to spread through the general aviation community as a whole. Business aircraft already appear to be frequent users of these technologies.

Increased Use of PIREPs. The SkySpotter Program, a collaborative training program of AOPA, the FAA, and NOAA, has been successful in training general aviation pilots in making and using PIREPs.

In *Aviation Weather Training*, the OFCM analyzed information about education and training programs received during data collection for the *Tier 3/4 Baseline Report*. The introduction to *Aviation Weather Training* reviewed the history of recommendations for improved aviation weather training since 1995 and the efforts that had been made in response to those recommendations (OFCM 2002). Data from course providers indicate strong pilot interest in these aviation weather offerings.

The Air Safety Foundation (ASF) and AOPA sponsor and approve courses for pilots as part of the Aviation Pilot Weather Education (APWE) program. The courses are developed and provided by contractors. From 1996 through the spring of 2003, the seminar-style course offerings had the following numbers of pilot attendees:

Aviation weather seminar	Attendees
Weather Strategies	25,880
Weather Tactics	19,605
Mountain Flying	1,556
Practical Weather Flying	289
“Never Again”	23,751
More “Never Again”	14,337
Operations at Towered Airports	19,622
SkySpotter	9,222

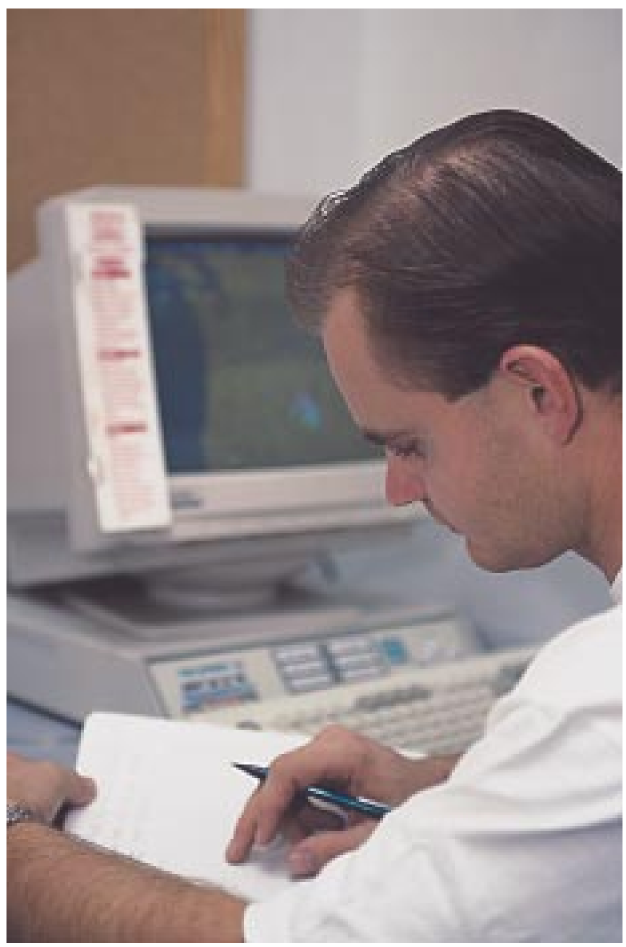
The annual numbers of attendees for the first seven of these courses (all but SkySpotter) were as follows:

Year	Attendees
1996	11,136
1997	12,287
1998	7,617
1999	27,494
2000	26,605
2001	7,052
2002	1,472
2003 (to date)	200

Beginning in 1999, ASF offered the seminars on Weather Strategies, Weather Tactics, “Never Again,” More “Never Again,” and Operations at Towered Airports as videos. The yearly distribution of these “seminars-in-a-box” is shown below:

Year	Sets distributed
1999	2,275
2000	2,025
2001	4,975
2002	6,050
2003 (to date)	3,275

In addition, in 2001–02, ASF sold the Weather Decision Making video to 41,758 pilots who had just received their instrument rating. Another 15,000 videos are likely to be mailed in 2003. The video stresses the importance of instrument flight rules (IFR) proficiency and working with the air traffic control (ATC) system to deal safely with convective storm hazards and other challenging weather. It addresses the limitation of ATC radar and discusses



Computer-aided instruction allows pilots to acquire and hone aviation weather skills using their home computers. © AOPA, all rights reserved.

how pilots can get the most value from preflight briefers, controllers, other pilots, Flight Watch, and other weather information sources (Sharitz 2003). ASF has been discussing collaboration aviation training programs with NOAA's National Weather Service (NWS).

As indicated in Table 11, the National Weather Association (NWA) currently offers two aviation weather courses on the Internet. As of spring 2003, the Thunderstorms and Flying course had been completed by 2,750 users of the NWA website. The Winter Weather and Flying course had been completed by 350 to 400 users.

Reducing Accidents for Part 135 Aviation

Part 135 aviation does not show the consistent downward trend since 1996 in the rate of all weather-related fatal accidents (Figures 3 and 4 in Section 2) that holds for general aviation. The Section 3 hazard category analysis shows that the problems are spread across hazards, and therefore across the aviation weather service areas (Table 2). An OFCM staff review of the Part 135 accidents in 1997 and 1998, as reported by the NTSB (NTSB 2002a, 2002b), found that the accidents occur across revenue service categories (scheduled versus nonscheduled, passenger and cargo) and across geographical regions. Anecdotes and opinions expressed by representatives from this aircraft regulatory category and by officials familiar with it suggest that multiple factors are involved.

Helicopters used for fighting wildfires are often Part 135 aircraft. Photo courtesy Dr. Timothy Brown, Desert Research Institute.

Diversity of Part 135 Operations and Services. Part 135 covers a broad range of niche applications, as well as small (less than ten passengers) scheduled air carriers and nonscheduled air taxi services (both passenger and

Part 135 aircraft in Alaska often fly passengers and cargo, using natural waterways as runways. Photo courtesy Wings of Alaska Airlines, © Mike Mastin.

cargo). Leased or chartered services provided by Part 135 aircraft, either fixed-wing or helicopter, include air taxi service, medical evacuation, and search and rescue. A variety of inherently dangerous aviation services, such as agricultural spraying, wildfire spotting, and emergency medical flights are included in the Part 135 mix. For some of these services, such as emergency medical flights or search and rescue, flying into or landing in hazardous weather conditions can be an essential part of the service provided.

Resource Constraints on Decision Support Structure. Unlike the Part 121 carriers, many Part 135 operations are small businesses with limited decision support infrastructure for the pilot either during flight planning or en route.

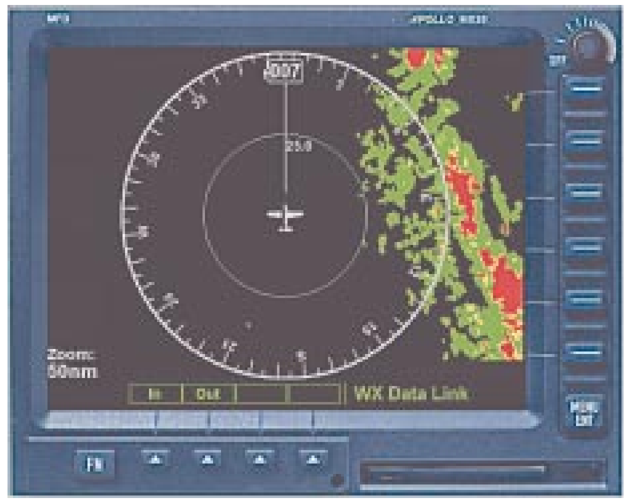
Resource Constraints on Upgrading Aircraft and Avionics. The small companies in this aircraft regulatory category often lack the financial resources to invest in new aviation weather technology, particularly when the up-front costs are substantial relative to the value of the aircraft. According to National Air Transportation Association (NATA) staff, more than 90 percent of the approximately 2,900 Part 135 operators have fewer than 25 employees and less than $5 million in annual revenue. More than 50 percent have five or fewer employees. Although 46 percent of the Part 135 fleet is turbine-powered, 60 percent of the fleet is more than 20 years old (Rosser 2003).

Reliance on Safety Infrastructure of Small Airports. According to NATA staff, adverse weather poses the highest risk to flight operations during the approach to the destination airport (or landing at a remote site, as in emergency rescue), rather than during the departure or en route phases of a flight. NATA has long advocated enhancing the weather services available to crews during the landing phase of flights, particularly at smaller general aviation airports and in rural areas. Ultimately, most small-aircraft Part 135 crews rely on government-sponsored resources for their flight weather information. However, according to NATA staff, long-promised equipment upgrades for some of these smaller destination airports, such as Automated Flight Service Station upgrades, often have not been implemented (Rosser 2003).

Differences from General Aviation Not in Revenue Service. Unlike most general aviation pilots, who fly at similar altitudes and also use smaller airports, Part 135 pilots and operators have strong economic incentives to meet prior flight commitments with respect to time and destination. Every Part 135 pilot undergoes mandatory initial and recurrent training, which is supervised and approved by the FAA and includes training and review on aviation weather topics. Although this training is in excess of that required for crews engaged in Part 91 operations, some of the Part 135 services (as noted above) call for flights through and landings during hazardous weather conditions.

With these broad characterizations in mind, the OFCM staff reviewed the aviation weather programs and projects to identify those in or nearing implementation that could make a difference to the accident experience of this aircraft category (as well as supporting the downward trends for the Part 91 and Part 121 categories). A key requirement is to bring together the advances in weather observation and forecast technology—which in principle are available to the entire aviation community—with the communications and information interpretation (decision support) technologies needed to deliver weather information to the Part 135 pilot. Further, real-world solutions must also be within the cost constraints of the business models within which these services operate.

The most promising initiative with potential for broad application to a range of weather hazards, within the constraints faced by a Part 135 pilot, is the weather information capability included in FAA's Safe Flight 21 program. Safe Flight 21 is a joint government-industry initiative to validate the capabilities of advanced communication, navigation, and surveillance technologies and related air traffic procedures. The key enabling technology on which Safe Flight 21 and its Alaskan Region demonstration program, **Capstone**, are based is Automatic Dependent Surveillance–Broadcast (ADS-B). ADS-B gives an aircraft with the requisite data uplink/downlink and cockpit display capabilities the same information about other aircraft in the vicinity as ATC now receives. For controllers, ADS-B provides a consolidated picture of the controlled airspace, especially aircraft operating in areas not covered by radar. ADS-B represents the technology implementation of the Free Flight concepts advocated by RTCA, Inc., and others in the aviation community, as those concepts have evolved over time (FAA 2003b, Scardina 2002, Lay 2003).



The Capstone demonstration program includes pilot training with simulated weather data on a multifunction display. A Part 135 pilot can use the display to show current weather radar data, air traffic, and terrain. Photo courtesy FAA Capstone program.

The direct relevance of this air traffic awareness system to aviation weather is that one of the two approved datalink technologies for ADS-B, the Universal Access Transceiver (UAT), will also provide an uplink for weather information via Flight Information Services–Broadcast (FIS-B). The weather data will be displayed on the same multifunction cockpit display used for the ADS-B display of traffic and for terrain data (Scardina 2002). A FIS-B capability, along with the ADS-B and Traffic Information Service–Broadcast (TIS-B), is being demonstrated in the Capstone program. For Capstone, the FAA provided up to 190 Part 135 aircraft in the region around Bethel, Alaska (the Yukon-Kuskokwim Delta Region) with an avionics package. The package consists of an IFR-certified global positioning system (GPS) receiver; the UAT, which provides ADS-B, FIS-B, and TIS-B data; a terrain database with capability for controlled-flight-into-terrain avoidance; and a multifunction color graphics cockpit display (CAASD 2003). The weather data being provided via FIS-B for

Capstone have included Next Generation Weather Radar (NEXRAD or WSR 88D), Terminal Aerodrome Forecasts (TAFs), and METARs (FAA 2003c). An FAA Capstone newsletter includes stories from Alaskan air taxi pilots indicating that these users are increasingly enthusiastic about the system, particularly its utility in instrument meteorological conditions (IMC) and the rapidly changing ceiling and visibility conditions of Alaska.[1]

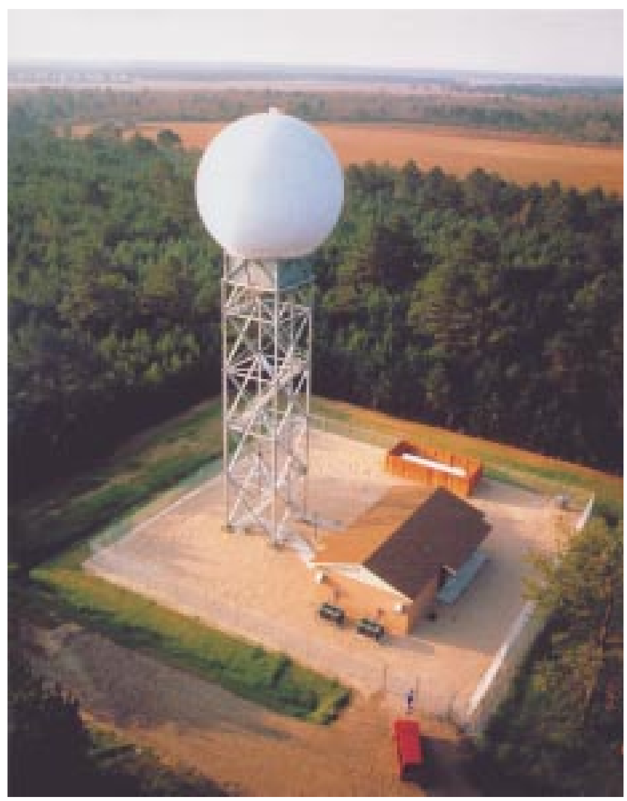
An interim deployment of the ADS-B technology on the U.S. East Coast was just beginning as of June 2003, with test and evaluation planned for 2004–05. The weather products that will be included in this deployment are still under evaluation. According to the FAA, when full deployment of ADS-B and FIS-B is achieved (2012 or later), coverage will be sufficient for Part 135 operations throughout the United States. The focus of Safe Flight 21 is on Part 91 and Part 135 aircraft. However, aircraft operators will need to install the UAT datalink technology (rather than the second ADS-B technology, the 1090 MHz Extended Squitter) to receive the FIS-B uplink data (Scardina 2002, FAA 2003c).

In summary, the FIS-B capability in Safe Flight 21 appears to offer a long-term solution for getting current weather information, along with terrain visualization, to the Part 135 pilot en route. This system will also benefit the Part 91 pilot, helping to extend the downward accident trends, hopefully to near-zero rates. Because much of the ground infrastructure for communications and information processing will be FAA or NOAA supported, and the weather information is packaged with the ADS-B technology, the cost of equipping aircraft is likely to be acceptable to the Part 135 industry and to most general aviation pilots/operators. (The avionics package provided for Capstone cost \$15,000–\$20,000 per aircraft in 2000 [Olmos and Mittelman 2000].) Once the data uplink is in place, additional information on weather hazards can be incorporated. Unfortunately, the current deployment schedule does not give coverage across most of the National Airspace System (NAS) until the 2007–12 time frame, which will not help in meeting the national aviation weather accident reduction goals by 2007.

Because of the diversity of aircraft operations covered by Part 135, particularly the range of aviation services offered, the hazard analysis for this assessment should be viewed as only highlighting a problem area that needs more detailed analysis. A case analysis of weather-related Part 135 accidents, with attention to grouping of accidents into relevantly similar flight/service conditions, would help shed light on the factors underlying the overall trends noted in this report.

Reducing Risk from Turbulence and Convection Hazards

The major air carriers (Part 121 aviation) have reduced fatal weather-related accidents to a rare event (see Table 3). Consequently, this mid-course assessment has turned to the record of weather factors cited in all accidents, fatal or not, to look for trends indicating which hazards remain a threat (see Table 4). As Table 4 and Figure 13 show, one hazard category, turbulence and convection hazards, accounts for substantially more than half of the citations in every year since 1995. If the trends of 1995 through 2001 continue, this single category would, by 2007, account for nearly all weather citations, every year, in Part 121 aviation accidents. These weather factors fall in three of the aviation weather service areas (see Table



TDWR is just one of the FAA-supported systems already implemented that can reduce the risks from turbulence and convection hazards. Upgrading these systems and extending coverage to more airports will reduce the risk of fatal accidents. Photo courtesy FAA.

[1]Issues of the newsletter are available at the FAA Alaskan Region website for Capstone: www.alaska.faa.gov/capstone.

2): convective hazards, terminal winds and temperatures, and turbulence.

Part 121 is not alone in facing turbulence and convection hazards. Although both the Part 91 and Part 135 data show *fatal* accidents for this hazard category trending to zero, the downward trends for *all* weather-related accidents do not show the desired 80 percent reduction by 2007 (Figures 10 and 17). Therefore, although progress in addressing turbulence has been substantial, a closer look is needed at what more can be expected from programs in progress and what additional efforts may be appropriate. The following review draws on programs and projects from all three turbulence-related service areas.

Flying in clouds and mountainous terrain, a pilot must be ready for turbulence and convection hazards, as well as sudden changes in visibility and ceiling. Photo courtesy Wings of Alaska Airlines, © Fred Hirschmann.

A newly operational weather product that should help Part 121 aviation avoid in-flight turbulence and convection hazards is the Graphical Turbulence Guidance (**GTG**) from the FAA's AWRP. This guidance for aviation weather forecasters is based in part on a recently developed turbulence forecast algorithm. The current operational algorithm gives numerical weather prediction models the capability to predict upper-level clear air turbulence above 20,000 feet (Flight Level 200). This makes the product primarily useful for Part 121 aviation. To produce a GTG product, the turbulence forecast is combined with turbulence observations, including PIREPs. Improvements to the turbulence forecast algorithm, expected during the next several years, will enable predictions for other sources of turbulence, such as terrain-induced and convective turbulence. AWRP plans to include guidance for turbulence down to 10,000 feet within the next year. These improvements could make the GTG more useful in forecasting turbulence relevant to the Part 91 and Part 135 aircraft categories.

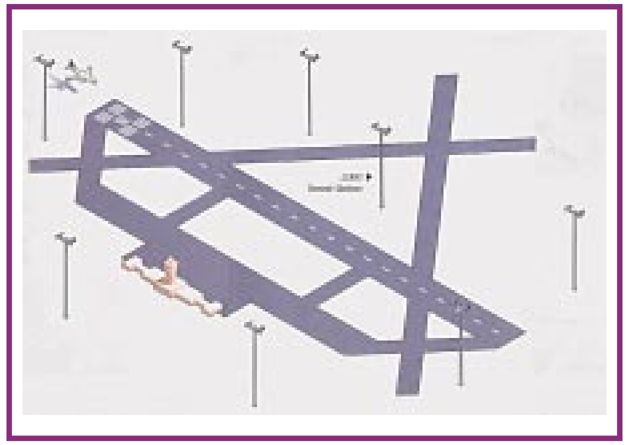
The AWRP is also developing the In-Situ Turbulence Algorithm (**ITA**), a promising new source of turbulence observational data, which will eventually be incorporated into GTG products. The ITA software package will reside in the Aircraft Condition Monitoring System (ACMS) of commercial air carriers. It converts high-rate vertical velocities and accelerations into an index of turbulence called the "eddy dissipation rate" (EDR), which is included in the ACMS real-time data downlink from the aircraft. The AWRP is continuing to develop and test the ITA, with the cooperation of several major air carriers. The International Civil Aviation Organization has approved the EDR approach used in the ITA as an international standard. In addition to improving the data ingest to turbulence forecast models, the ITA's real-time, objective, and quantitative reports will be valuable in verifying forecasts and validating models—an essential tool for continuing to improve forecast skill. Given the success of the approach, the capability to incorporate it into an existing data stream (the ACMS), and the potential value of the data for reducing risks from in-flight turbulence, the ITA could provide substantial benefits and should be continued.

Another approach for warning aircraft is to detect turbulence ahead, using on-board sensor systems. NASA is currently implementing a system that uses an aircraft's on-board weather radar to detect clear-air turbulence (**RADAR**). It is also working cooperatively with industry on a Light Detection and Ranging (**LIDAR**) sensor system to detect clear air turbulence. The LIDAR approach is a longer-term technology development effort than the radar approach.

The Turbulence Plot System (**TPS**) provides messages on turbulence and other weather factors to the cockpit for in-flight tactical decisions. This industry-developed system (developed by Northwest Airlines) uses aviation meteorologists to gather information from many sources and produce reports of hazardous weather conditions, for distribution to dispatchers and pilots. The system now covers eight weather hazards: clear air turbulence, mountain wave turbulence, thunderstorm activity, low altitude frontal wind shear, low altitude convective wind shear, volcanic ash, icing, and ozone. Text-formatted messages are transmitted in a standard format called the Turbulence Plot Message. The TPS incorporates detailed procedures for hazard avoidance and training modules for pilots, dispatchers, and meteorologists. ARINC has developed a system to display the Turbulence Plot Message graphically and is making it available to other airlines via a redistribution agreement with Northwest Airlines. This is an example of leveraging the product of an industry partner to achieve substantial results of value for the Part 121 aircraft category. At some point, an independent test and evaluation of TPS may be useful for encouraging its adoption or improving it for more widespread use.

Several weather factors in the turbulence and convection hazard category are relevant to terminal environments during departure and landing. These factors come under the service areas for convective hazards or terminal winds and temperatures.

Fortunately, there are a number of programs and projects that are in implementation now or will be ready for implementation in the near term and that can help forecast, detect, or warn of these hazards. The FAA's **WSP** (a modification for terminal surveillance radar), **MIAWS**, **TDWR**, and Low Level Windshear Alert System (**LLWAS**) are among the already implemented systems that provide direct observation of these near-terminal weather hazards. Within three to five years, the FAA plans to complete implementation of these systems, which were included in a national aviation weather initiative to expand the number of airports at which microburst and low-level wind shear services are available (OFCM 2001, pp. 3–6; FAA 2003a, p. 8). In addition, the Terminal Convective Weather Forecast (**TCWF**), Wind Gust Potential Product (**WGPP**), and Weather Research and Forecasting (**WRF**) model are FAA-supported products or forecast development programs that will aid in forecasting these hazards. The NOAA-supported Dallas-Fort Worth Collaborative Aviation Forecast Study (**DCAFS**) will also help. Systems to disseminate observational and forecast products to air traffic control and pilots include the Flight Information Services Data Link (**FISDL**) for general aviation aircraft, the FAA's Operational and Supportability Implementation System (**OASIS**) for workstations at Automated Flight Service Stations, and NASA's Weather Information Communications (**WINCOMM**) datalink technologies for graphical cockpit display. Among the industry-led efforts are Automatic Delivery of Wind Shear Alerts (**ADWSA**) and the TPS (described above). The NASA WINCOMM project is developing satellite-communicated delivery of wide-band graphical products to the cockpit, including terminal hazard alerts, through cooperative research agreements (CRAs) with industry. One such effort involves the test and evaluation of a worldwide weather datalink capability using broadcast Satellite Digital Audio Radio Service (**S-DARS**).



The FAA-developed Low Level Windshear Alert System uses multiple wind sensors arrayed around the terminal area to detect wind shear and alert aircraft and controllers. Image courtesy FAA.

Continued support for these R&D and implementation programs in progress is important to reap the benefits they offer for reducing the risks from turbulence and convection hazards. For many of the operational systems and products that are already available, as well as for those soon to be available, implementation at smaller or less-busy airports is constrained by budgets. In an environment of budget cutbacks at federal agencies and economic difficulties for airlines and the aviation industry generally, there are pressures to curtail the investments in technology needed to reduce fatal accidents involving terminal area turbulence and convection hazards. The continuing risk from these hazards in all three aircraft regulatory categories shows that completion of the work in progress is a worthwhile R&D investment for the nation.

Reducing Risk from High Density Altitude

High density altitude is a weather factor in the terminal winds and temperatures service area (see Table 3). As the text box below explains, density altitude is a criterion for the combined effects on aircraft flight performance of temperature, altitude, and humidity. Additional factors are the particular airframe, engine, fuel-air composition feeding the engine, and weight and balance of the loaded aircraft. If a sufficiently knowledgeable pilot has current, correct data on all these factors and has adequate time to make the necessary computations and weigh all the interacting, relevant factors, the pilot should be able to avoid an accident due to high density altitude. The trends in the frequency at which this factor is cited for general aviation, and even Part 135, accidents indicate that pilots continue (not surprisingly) to have problems with density altitude (see Table 3 and Figures 11 and 18). The problem can, and should, be attacked on three fronts.

1. Accurate data are needed on the conditions (temperature and humidity) for the location and time at which a pilot will be in a situation where density altitude matters most (typically takeoff and landing, but also during high power-required conditions in flight). For takeoff, this probably means current temperature and humidity on the runway and in the flight path during ascent. For landing, it may mean an accurate forecast of those weather parameters when the plane is scheduled to be approaching, available during flight planning, as well as current observations just prior to approach for landing.
2. The multiple factors involved in determining density altitude (including the effects of humidity on engine performance) and assessing how it will affect a particular aircraft's airframe, engine, and loading constitute just the kind of problem that an information-technology-based decision support capability can solve for the pilot.
3. Even with a good decision support tool, the pilot needs to know how to respond to the advice (or output) offered by the tool. Education about density altitude and training in how to get the necessary input data and derive the right answer will be essential to success, even when much better decision support tools are on the market.

Density Altitude—Hot, High, and Humid Air

Density altitude is a flight performance factor, not a measure of altitude. Roughly, it measures the effects of air temperature, altitude (usually, the elevation of a takeoff or landing), and humidity on the performance of the aircraft. Aircraft manufacturers provide information on a general aviation aircraft's performance under standard atmospheric conditions corresponding to sea level and 59 °F. When the air is less dense than under these standard conditions, there is less air flowing over the camber of the wing. The aircraft experiences less lift at a given airspeed than at the standard conditions. Air that is warmer or at a higher altitude than the standard conditions is less dense. Density altitude is a measure of how much less dense the air is than it would be at standard conditions. In particular, higher temperatures at high elevations substantially increase the density altitude.

Density altitude effects are not confined to mountain areas. They also can be serious at lower elevations if temperatures are well above the standard 59 °F. In these conditions, the third factor in density altitude, humidity, magnifies the air-thinning effect of temperature. The amount of water vapor in the air affects the engine power rather than the aerodynamic efficiency of the aircraft. At 96 °F, the water vapor content of the air can be eight times greater than at 42 °F. Exactly how a higher humidity will affect engine performance (and thus the "altitude" the aircraft appears to be experiencing) depends on the particular engine and its fuel-air mixture (lean versus rich). The Koch chart often used to figure the effect of temperature on the density altitude at a given elevation does not explicitly include the humidity factor. The FAA recommends that pilots departing in humid, warm conditions add an additional 10 percent to their computed takeoff distance and anticipate a reduced climb rate.

As density altitude increases, takeoff distance, power available (in normally aspirated engines), and climb rate are adversely affected. Density altitude also increases the difference between indicated airspeed (it is lower) and true airspeed, an effect that can increase landing distances significantly beyond what a pilot is expecting. Weight and balance are also factors that pilots must take into account at high density altitudes, as stall conditions are affected.

Sources: FAA 2003d, FAA 2003e.

Sustaining Progress in Reducing Risks from Frequently Cited Weather Factors

The progress toward accident reduction goals for Part 91 aircraft in weather-related accidents has been substantial, but the ten-year goals have not yet been achieved. Among the factors that continue to cause fatal accidents each year are fog and low ceiling, which fall in the ceiling and visibility service area. Some of the programs for the ceiling and visibility service area that will address these weather factors are discussed below.

The terminal winds and temperatures service area comprises a number of factors that continue to be cited each year in multiple fatal accidents, including gusts and terminal area winds (tail wind, crosswind, or high winds). The programs discussed above for addressing turbulence and convection factors in the terminal area will also address these hazards.

The national initiative to address en route ceiling and visibility hazards through weather product development is led by the National Ceiling and Visibility (**NCV**) Product Development Team within the FAA's AWRP. At present, the NCV Product Development Team has two products in the testing stage: an analysis product and a forecast product. These products are scheduled to become experimental in FY 2005 at the AWC and operational in FY 2006–07. Key partners in the development efforts have included NCAR, the Naval Research Laboratory, Massachusetts Institute of Technology (MIT) Lincoln Laboratories, and NOAA's FSL.

The Terminal Ceiling and Visibility (**TCV**) Product Development Team of the AWRP has been working on the Marine Stratus Forecast System (**MSFS**), which produces near-term (0 to 6 hour) predictions of when marine stratus formations will lift. Another TCV product will provide ceiling and visibility forecasts for airports where IMC commonly result from large weather systems during the winter season in the Northeast.

NASA, which was a partner in the early work of the NCV Product Development Team, is now working in collaboration with the FAA on a related effort, the Advanced Satellite Aviation Products (**ASAP**). The Phase I product will make better use of current weather satellite data in aviation applications that include ceiling and visibility observations and forecasts. Phase II of ASAP, scheduled to begin in FY 2006, will focus on incorporating high-resolution (spatial and temporal) data on winds, atmospheric temperature, and moisture, which will become available from a geostationary operational environmental satellite (GOES) in the 2010–12 time frame. The improved resolution of water vapor and winds will enhance numerical weather prediction modeling, as well as improve dispersion forecasts of volcanic ash plumes.

A ceiling and visibility product produced from the current GOES is the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) Low Cloud Product (**LCP**). The LCP, which helps forecasters establish areas of widespread low clouds, is scheduled for incorporation in the NWS Advanced Weather Interactive Processing System (**AWIPS**) early in FY 2004. As further refinements are made to the LCP, they will be incorporated into this AWIPS-distributed product for weather forecasters and aviation meteorologists.

An aircraft's instrument panel is crowded with information the crew must assimilate. Incorporating graphical weather information on multifunction displays can ease the information load. Photo courtesy FAA Capstone program.

Highlights of Past, Current, and Future Implementations

The preceding section discussed aviation weather programs and projects of direct relevance to the conclusions from the accident analysis. Other entries in Table 10 are indirectly relevant because they supply general supporting capability. For example, dissemination systems or decision support and cockpit display infrastructure are needed to communicate turbulence information to pilots. In principle, these same systems should be communicating and processing information on all the other weather hazards the pilot is facing, as well as other aviation safety information. (The Safe Flight 21 program described above illustrates this integrated approach.)

In addition, many of the Table 10 projects either have contributed already to reducing accident rates, or they will sustain and improve the progress already made, as implementation begins or expands throughout the NAS. Terminal and en route icing forecast products, as well as de-icing decision support systems, are among the examples in this category. Other projects, such as systems to observe and forecast models to predict atmospheric transport of volcanic ash plumes, address known hazards that need to be avoided, even though they do not show up in the NTSB accident data during the period analyzed for this assessment.

The gist of the rationale for each project is represented in the user benefit column in Table 10. This section provides an overview of the breadth of activities under way by highlighting a few of the most important efforts in each of the five product/service categories (the main product column in Table 10). Programs were selected for discussion based on their likely impact on weather-related accident rates, their contribution to a safer and more efficient NAS, and the extent of partnering they involve, both among federal agencies and across public–private sector boundaries.

Weather Product Development

The Collaborative Convective Forecast Product (**CCFP**), which became operational in May 2000, illustrates successful partnering among the FAA, NOAA, and airline meteorologists. Convective activity has been the single most frequent source of weather-related delays and disruptions in the NAS. CCFP is reducing these disruptions by providing air traffic flow managers (e.g., airline dispatchers) and air traffic controllers with a more accurate forecast of convective weather (AWC 2003). Convective activity is also a major source of turbulence and convection hazards.

The forecasts produced are *collaborative* because an AWC forecaster develops a preliminary forecast, on which the Center Weather Service Units and airline meteorologists comment, based on their respective areas of responsibility. The AWC forecaster uses this input, received in real time via a restricted-access Internet chat room, to revise the final forecast product before posting it on the CCFP website at the published issue time. Beginning in July 2002, the frequency of CCFP issuance increased from a four-hour to a two-hour cycle. End users include the ATC System Command Center, airline dispatchers, airline area of concern/ATC coordinators, and traffic management units at airports (AWC 2003). CCFP forecasts are available to the general aviation community via **ADDS**.

To improve the CCFP over time, the convective forecasts are compared with actual weather conditions for accuracy. Statistical results are computed by the Real-Time Verification System, operated by NOAA's FSL and supported by the FAA's AWRP through its Quality Assessment Product Development Team. Thus, the value of CCFP to the NAS should increase over time.

The **WRF** model, mentioned above as an indirect contribution to dealing with turbulence hazards, is a multiyear development project being undertaken by a coalition of public-private partners. The principals include NOAA, through its National Centers for Environmental Prediction (NCEP), FSL, and National Severe Storms Laboratory; NCAR; the U.S. Air Force Weather Agency (AFWA); the National Science Foundation; the U.S. Navy; and the Center for Analysis and Prediction of Storms (CAPS) at the University of Oklahoma. The two major goals of this effort are (1) to develop an advanced mesoscale forecast and data assimilation system, and (2) to promote closer ties between research and operations. A basic WRF version, incorporating simple model physics, was released to the community for testing and evaluation in 2000. However, the operational impact of WRF for aviation weather is just beginning.

WRF is already being tested for many forecast applications. Testing for initial operational use at NCEP, AFWA, and FSL is under way, with implementation in operations scheduled for late 2004. For aviation weather, its principal benefits include a design that can accommodate horizontal grids of 1 to 10 km and improved forecast accuracy and efficiency across a broad range of scales. AFWA, for example, is using WRF for real-time applications at synoptic scales (e.g., the continental United States). Other applications are using WRF for regional and storm-level forecasting. Improved forecasts of weather-related variables that affect aviation will improve the safety and efficiency of NAS operations.

Volcanic ash plumes are a hazard for international flights by U.S. aircraft, as well as being a hazard within the NAS downwind from volcanic activity (e.g., Alaska and Hawaii). NOAA's Volcanic Ash Forecast Transport and Dispersion Model (**VAFTAD**) is already in use for forecasting ash dispersion. VAFTAD will soon be replaced by the Hybrid Single Particle Lagrangian Integrated Trajectories

(**HYSPLIT**) model for improved dispersion forecasting. The Volcanic Ash Product (**VAP**) and Volcanic Ash Graphic (**VAG**) are volcanic ash detection and ash advisory products NOAA is now implementing. The FAA's AWRP is working on a Volcanic Ash Warning (**VAW**) product to help aircraft avoid volcanic ash over the oceans. Volcanic ash detection and plume migration forecasting will be improved further when the Geosynchronous Imaging Fourier Transform Spectrometer (**GIFTS**) is incorporated in the next generation of geostationary weather satellites. These and other projects and initiatives to deal with the volcanic ash plume hazard to aviation will be topics for discussion at a summer 2004 symposium on volcanic ash and aviation safety.

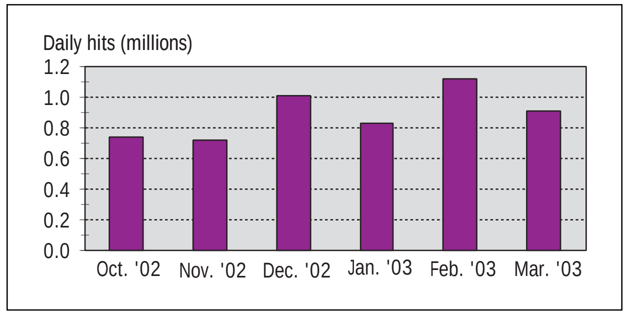
Weather Product Dissemination

Before products such as CCFP and the emerging applications of WRF can improve aviation safety, users must have access to them in a form relevant to their decision-making processes. As noted above, CCFP forecasts are available via the Internet for the strategic traffic management decisions made by air traffic controllers and traffic flow managers. Another Internet-based dissemination system, aimed at the entire aviation community and particularly useful to general aviation pilots, is **ADDS**, which was discussed above as one factor reducing the accident rates for general aviation. The products available at the ADDS website (adds.aviationweather.gov) include experimental weather products. As noted previously, representatives of general aviation pilots report that this community finds the ADDS site extremely useful—another sign that the education and training programs in aviation weather are reaching this important audience.

The first version of ADDS was turned on for Internet access in 1997, with a more user-friendly interface added in 1998. It won a Government Technology Leadership Award in 2000. A recent improvement is a flight path tool, which provides user-friendly graphics about turbulence, icing, thunderstorms, and other weather hazards for user-specified flight altitudes and flight paths. ADDS is already being accessed routinely by pilots. Figure 20 shows the average *daily* hits (user accesses to the website) each month from October 2002 through March 2003. Figure 21 shows which weather products available on ADDS were accessed most frequently during March 2003.

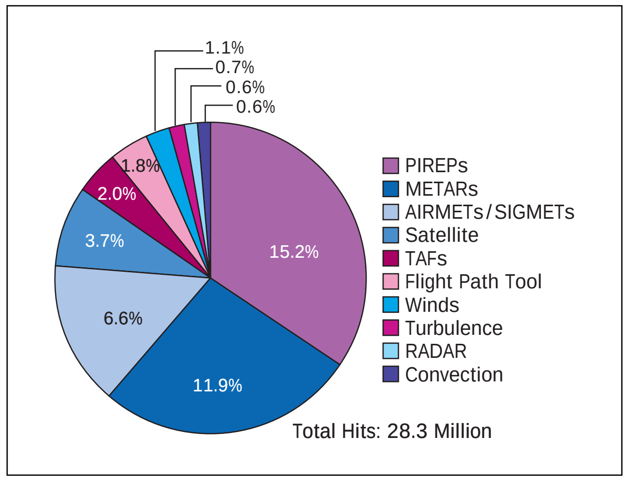
With the already planned improvements to ADDS and its potential to disseminate just-emerging weather prod-

Figure 20. Average daily hits on the ADDS website



Source: Mahoney 2003.

Figure 21. Top ten weather products on ADDS, by number of hits in March 2003



Source: Mahoney 2003.

ucts, ADDS will continue to improve the delivery of useful weather information to the aviation community through the remainder of the ten-year evaluation period.

Education, Training, and Outreach

As discussed above in relation to the trends of decreasing weather-related accidents for Part 91 aviation, pilot-oriented education and training courses in aviation weather appear to be a major contributing factor in the accident reduction rates observed since 1996. The earlier discussion included course statistics for two of the programs listed in Table 11, the APWE program by AOPA/ASF and the NWA's Internet-delivered courses. As Table 11 indicates, there are a number of other programs, most with multiple course offerings. Although OFCM staff have attempted to make the listing comprehensive, it probably does not capture all the offerings available.

The Cooperative Program for Operational Meteorology, Education and Training (**COMET**) offers a broad array of meteorology-related courses and programs. The course offerings listed for COMET in Table 11 represent just those with direct relevance to aviation weather. A difference between these courses and APWE or NWA offerings is that the COMET courses are typically oriented to aviation weather support specialists—e.g., aviation meteorologists and operational forecasters—rather than pilots.

The downward trend for general aviation in the rate of accidents involving icing hazards (Figure 9)—particularly when compared with an apparent upward trend for Part 135 (Figure 16)—suggests that general aviation pilots are more often taking appropriate precautions. These precautions may include staying away from reported or forecast icing conditions or escaping quickly if such conditions are encountered en route. NASA's Education and Training Program (**E&T**) has been a major contributor to the training and information sources available to the general aviation community. The videos listed in Table 11 for this NASA program are distributed at low cost through a pilot-oriented direct mail/Internet supplier.

Tables 10 and 11 list three new NOAA/NWS training initiatives: the Aviation Operations Course (**AOC**), Distance Learning Aviation Course (**DLAC**), and Pilot Training Initiative (**PTI**). The AOC, which is intended to train forecasters on the operational impacts on aviation of forecast products and preparation of TAFs, is being developed by the NWS Training Center and will probably be implemented within a year or two. The DLAC, developed by the NWS Training Center and COMET, combines distance learning (teletraining) and on-line exercises. The target audience is aviation weather focal points at Weather Forecast Offices. These focal points are expected to train other forecasters at their Weather Forecast Office. A DLAC Forecasting Fog and Stratus module is available now. A module on convective forecasting is planned for implementation within a year or two. The PTI is still in the planning stage, and there are encouraging signs that a collaboration between NWS and AOPA will be used for this initiative, which will focus on weather training for pilots.

In *Aviation Weather Training*, the Federal Coordinator for Meteorological Services and Supporting Research noted the need to "find and facilitate opportunities to leverage and collaborate on training among the federal agencies, industry, universities, and, where appropriate, the private sector" (OFCM 2002, pp. 2–18). That report identified opportunities to reduce training redundancies, improve access to needed training, and minimize training development costs. Further coordination is needed among the developers and providers of aviation training courses and materials listed in Table 11 to ensure that the entire aviation community has access to training that can reduce accidents, save lives, and improve the efficiency of NAS operations. Signs that the AOPA and NWS are working toward collaborating on pilot training courses are encouraging, but the players in the education, training, and outreach arena can go much further in leveraging efforts and collaborating to reach the target audiences with the greatest effectiveness and efficiency. The progress made in Part 91 accident reduction since 1996 shows that educating the general aviation community and providing them with access to the information for informed decision making is an effective approach.

Meetings and gatherings of the aviation community in which aviation weather is a program focus are often the first step in informing the community about the scope and value of course offerings and training materials, such as videos. These gatherings also can provide a venue where developers and vendors of course content and materials meet and develop collaborative approaches. Recent and upcoming outreach events are listed below.

- Experimental Aircraft Association (EAA) Airventure 2003; July 29–Aug. 4, 2003; Oshkosh, WI
- 72nd National Association of State Aviation Officials Annual Convention and Trade Show; Sept. 20–23, 2003; Charlotte, NC
- National Business Aviation Association Meeting; Oct. 7–9, 2003; Orlando, FL
- Friends/Partners in Aviation Weather Forum; Oct. 8, 2003, Orlando, FL
- NWA Annual Meeting; Oct. 18–23, 2003; Jacksonville, FL
- AOPA Expo 2003; Oct. 30–Nov. 1, 2003, Philadelphia, PA
- Second International Conference on Volcanic Ash and Aviation Safety; summer 2004

Following are past and recurring events with aviation weather interests.

- Various conferences conducted by American Meteorological Society committees such as the Aviation, Range, and Aerospace Meteorology Committee and the Broadcast Meteorology Committee
- Annual meetings of the Friends/Partners in Aviation Weather

- Annual meetings of the NWA
- Meetings of the Air Transport Association's Meteorology Committee
- Annual reviews of the FAA's Aviation Weather Research Program
- Annual reviews of NASA's Weather Accident Prevention project
- Meetings of RTCA, Inc., special committee on with-flight information services (SC 195)
- Annual AOPA expositions
- Annual Airventures, sponsored by EAA
- Various conferences and forums sponsored by the FAA, such as the In-Flight Icing/Ground De-Icing International Conference held in June 2003 in Chicago, IL
- Meetings of the American Institute of Aeronautics and Astronautics
- OFCM Aviation Weather User Forum, July 25–26, 2000, Bethesda, MD (see OFCM 2000 for proceedings)

Cockpit Displays

As the specificity and diversity of weather hazard information available in the cockpit increases, information overload of the pilot (or flight crew, on large aircraft) becomes an issue. Decision support capabilities and systems, which digest and interpret details into a decision-ready form, are part of the solution and are discussed below. Multifunction displays with well-designed graphics are another essential part of the solution. Particularly important is the integration of weather-related information with other flight information (flying parameters, terrain, ATC instructions) that require continual pilot/crew attention. For example, the multifunction display being used in the **Capstone** demonstrations in Alaska, as part of FAA's Safe Flight 21 program, provides real-time information on three-dimensional terrain, airspeed, groundspeed, air traffic (ADS-B), and GPS Wide Area Augmentation System location, as well as graphical and text weather information.

The instrument panel of a Part 135 aircraft participating in the Capstone demonstration program. Note the multifunction display showing weather radar data. Photo courtesy FAA Capstone program.

The private sector is responding to the potential market for weather-oriented cockpit displays. Cockpit display technology developed by NASA and Honeywell through a CRA is now being incorporated in Honeywell avionics products. For the general aviation market there are a number of weather datalink services, some with specialized cockpit display hardware.

Decision Support Systems and Capabilities

The FAA-developed Integrated Terminal Weather System (**ITWS**) processes and displays current and predictive weather information for the use of terminal air traffic management personnel. It is designed to support both safety and traffic planning objectives. For observational data, ITWS integrates data products from various FAA and NWS sensor systems, including TDWR, Airport Surveillance Radar–9 (ASR-9), NEXRAD (WSR 88D), **LLWAS**, and Automated Surface Observing System (**ASOS**). It also draws on the Meteorological Data Collection and Reporting System (**MDCRS**) and the NOAA Rapid Update Cycle (**RUC**) numerical weather prediction model. These sources are used for 20-minute nowcasts (conditions for the next 20 minutes), as well as for displaying current conditions. Products generated by ITWS include observed and forecast wind shear and microburst activity; information on storm cells, lightning, precipitation, terminal area winds aloft, and runway winds; and nowcasts of ceiling and visibility.

ITWS is an advisory tool for both strategic and tactical planning of the terminal airspace. The ITWS situation display, from which users work, includes an alert panel with six alert boxes, plus one or more weather windows for user-selected maps of current weather conditions and forecasts. The weather maps can cover from 5 to 200 nm out from the selected airport.

Prototypes of this FAA-funded decision support system have been in use at several airports since 1993. Feedback from these users has been a key factor in evolution of a useful and reliable system. A contract for the production system was awarded in January 1997. Thirty-seven systems will be installed by the end of FY 2003.

NASA's Aviation Safety Program, along with its industry partners, is making a significant investment in developing advanced cockpit displays that incorporate decision support capabilities. These synthetic vision systems (**SVS**) combine enhanced GPS location technology with high-resolution terrain databases to give pilots a three-dimensional graphical display of terrain around their flight path, regardless of the prevailing visibility conditions (NASA 2003). One such system, the Synthetic Vision/Highway in the Sky technology from Chelton Flight Systems, was recently approved by the FAA. A Chelton Flight Systems synthetic vision system is also part of the **Capstone** avionics suite and uses the same multifunction display as the NEXRAD (WSR 88D) maps and other weather information provided via the FIS-B communications datalink (Chelton Flight Systems 2003, CAASD 2003).

During the two decades from 1980 to 2000, much work was done on de-icing technology and on support tools to aid in deciding when and how best to de-ice aircraft. The FAA Winter Weather Product Development Team developed the Weather Support to De-Icing Decision Making (**WSDDM**) system to produce one-hour to two-hour nowcasts in real time of freezing or frozen precipitation in the terminal area, using Doppler weather radar, surface weather data, and snow gauges to determine precipitation type, temperature, wind speed and direction, and the liquid water equivalent of falling snow. The WSDDM technology was transferred in 1999 to a commercial developer and is now operational at the three major airports in the New York City area. The research on which WSDDM is based has also led to changes in how de-icing decisions are made by major airlines.

FISDL is a commercially available subscription service uplink to provide text and graphic flight services information, including both text and graphical weather products, to the cockpit. It is intended for use by the general aviation community.

The **Safe Flight 21** program, with its combination of ADS-B, TIS-B, and FIS-B communications links, a supporting ground infrastructure, and a multifunction cockpit display, illustrate the future direction of decision support systems for the general aviation and small-carrier pilot. Unfortunately, the full impact of Safe Flight 21 will not occur until well after the ten-year milestone for reducing aviation accidents related to weather.

Table 5. FAA-led aviation weather programs

Service area	Weather product development	Weather product dissemination	Education, training, and outreach	Decision support systems and capabilities
Ceiling and visibility	ADDS AWOS/ASOS RUC WRF NCV TCV	FISDL CDMNET WMSCR OASIS ADAS FBWTG	FAA Academy -ASOS -METAR/TAF -Basic Aviation Weather -Severe Weather -Integrated Terminal Weather System -Automated Weather Sensors System	MSFS RVR Capstone
Convective hazards	ADDS NCWF OCTH OACD OACN RUC WRF RCWF PA CA MRC AWOS/ASOS	FISDL CDMNET WMSCR OASIS ADAS FBWTG	FAA Academy -Basic Aviation Weather -Severe Weather -Weather System Processor -Integrated Terminal Weather System	WARP CIWS TDWR Capstone
En route winds and temperatures	ADDS MDCRS RUC WRF WVSS	FISDL WMSCR OASIS FBWTG	FAA Academy -Basic Aviation Weather -Integrated Terminal Weather System	WARP
Ground de-icing	AWOS/ASOS		FAA Academy -Ground De-Icing, Anti-Icing Operations -Basic Aviation Weather -Integrated Terminal Weather System	WSDDM
In-flight icing	ADDS CIP FIP WVSS RUC WRF SBID GRIDS PA	FISDL WMSCR OASIS FBWTG	FAA Academy -In-Flight Icing -Basic Aviation Weather -Integrated Terminal Weather System	WARP
Terminal winds and temperatures	ADDS TCWF MDCRS AWOS/ASOS RUC WRF JAWS CA	FISDL WMSCR OASIS ADAS FBWTG	FAA Academy -Low-Level Wind Shear Alert System -Basic Aviation Weather -Severe Weather -Integrated Terminal Weather System -Automated Weather Sensors System	ITWS MIAWS LLWAS-NE Capstone TDWR WSP
Turbulence	ITA GTG MDCRS OITFA RUC WRF NTDA ADDS	FISDL WMSCR OASIS FBWTG	FAA Academy -Wake Turbulence -Basic Aviation Weather -Severe Weather -Integrated Terminal Weather System	WARP Capstone
Volcanic ash	VAW	WMSCR FBWTG		

Legend: Already implemented (FY 1997-2002)
In implementation now (FY 2003–04)
Future implementation planned or scheduled for FY 2004–07 time frame

Table 6. NASA-led aviation weather programs

Service area	Weather product development	Weather product dissemination	Education, training, and outreach	Decision support systems and capabilities
Ceiling and visibility		WINCOMM		AHAS SVS AWIN
Convective hazards		WINCOMM		AHAS AWIN
En route winds and temperatures	TAMDAR ASAP GIFTS	WINCOMM		AHAS AWIN
Ground de-icing				
In-flight icing	TAMDAR ASAP	WINCOMM	PC-based Icing Simulator Education and Training -Icing for General Aviation Pilots -Tailplane Icing -Icing for Regional & Corporate Pilots -A Pilot's Guide to In-Flight Icing	AHAS AWIN
Terminal winds and temperatures		WINCOMM		AHAS AWIN
Turbulence	TAMDAR ASAP	WINCOMM		AHAS RADAR LIDAR AWIN ALDA
Volcanic ash	ASAP	WINCOMM		AHAS AWIN

Legend: Already implemented (FY 1997-2002)
In implementation now (FY 2003–04)
Future implementation planned or scheduled for FY 2004–07 time frame

Table 7. NOAA-led aviation weather programs

Service area	Weather product development	Education, training, and outreach	Decision support systems and capabilities
Ceiling and visibility	ASOS LCP WRF TAF GAF	NWS Training Center –Forecasting Low Level Clouds/Fog for Aviation Ops NWS Aviation Operations Course NWS Distance Learning Aviation Course NWS Pilot Training Initiative	AWIPS
Convective hazards	ASOS NLDN WRF TAF CCFP GAF	NWS Training Center –Severe Convection Forecasting and Warnings	AWIPS CCFP
En route winds and temperatures	WRF AWIPS	NWS Training Center –Low Level Wind Shear	AWIPS
Ground de-icing	ASOS		
In-flight icing	AIP WRF MMCR AWIPS	NWS Training Center –Forecasting Icing NWS Pilot Training Initiative	AWIPS
Terminal winds and temperatures	ASOS WGPP WRF TAF GAF	NWS Training Center –Low Level Wind Shear	AWIPS DCAFS
Turbulence	MWAVE WRF	NWS Training Center –Forecasting Turbulence –NWS Pilot Training Initiative	AWIPS
Volcanic ash	VAFTAD VAG VAP HYSPLIT		

Legend: Already implemented (FY 1997-2002)
In implementation now (FY 2003–04)
Future implementation planned or scheduled for FY 2004–07 time frame

Table 8. DOD-led aviation weather programs

Service area	Weather product development	Weather product dissemination	Education, training, and outreach	Decision support systems and capabilities
Ceiling and visibility	CDFS II N-TFS GTWAPS WRF C&V NAAPS ASOS NITES SMOOS (R) METMF MIDDS-T TAM	OPS II IMETS NFWB TEDS	Qualification Training Packages -Metwatch -Flight Weather Brief -Weather Elements	AMS TMOS RAWS
Convective hazards	N-TFS GTWAPS WRF NITES NSDS-E MRS ESID LPATS MIDDS-T TAM ASOS METMF OPUP	OPS II IMETS NFWB TEDS	Qualification Training Packages -Convection -Flight Weather Brief -WSR-88D PUP	AMS TMOS TWR SWR TEP
En route winds and temperatures	GTWAPS WRF NITES MIDDS-T METMF MRS	OPS II NFWB TEDS	Qualification Training Packages -Metwatch -Flight Weather Brief	MMS-P
Ground de-icing	ASOS		Qualification Training Packages -Weather Elements -Flight Weather Brief	AMS
In-flight icing	N-TFS WRF NITES NSDS-E METMF	OPS II IMETS NFWB TEDS	Qualification Training Packages -Weather Elements -Flight Weather Brief	IRP
Terminal winds and temperatures	N-TFS AOS GTWAPS WRF ASOS NITES SMOOS (R) MRS METMF	OPS II IMETS NFWB TEDS	Qualification Training Packages -Metwatch -Flight Weather Brief -Weather Elements -Convection	AMS TMOS RAWS TEP
Turbulence	N-TFS WRF MWFM NITES NSDS-E TAM METMF	OPS II IMETS NFWB TEDS	Qualification Training Packages -Turbulence -Flight Weather Brief -Convection -Weather Elements	
Volcanic ash	PUFF NAAPS	OPS II	Volcanic Ash Computer Based Training	

Legend: Already implemented (FY 1997-2002)
In implementation now (FY 2003–04)
Future implementation planned or scheduled for FY 2004–07 time frame

Table 9. Aviation weather programs led by universities, industry, and associations

Service area	Weather product development	Weather product dissemination	Education, training, and outreach	Cockpit Display	Decision support systems & capabilities
Ceiling and visibility	FFP	FISDL VDLM2	Aviation Pilot Weather Education -Weather Strategies -Weather Tactics -Mountain Flying -Practical Weather -"Never Again" -Operations at Towered Airports -SkySpotter Aviation Weather Hazards COMET EWINS NWA Internet Courses -Thunderstorms and Flying -Winter Weather and Flying		WebASD
Convective hazards	Hub-CAPS ATLAS AWIN CRA3 GLDI AWHCS	TPS AWIN CRA1 AWIN CRA2 S-DARS CRA SWIS-CRA WxITC FISDL VDLM2	Aviation Pilot Weather Education -Weather Strategies -Weather Tactics -Mountain Flying -Practical Weather -"Never Again" -Operations at Towered Airports -SkySpotter Aviation Weather Hazards COMET NWA Internet Courses -Thunderstorms and Flying	WINN	DA AWARE EWxR CRA WebASD
En route winds and temperatures	AWIN CRA3 AWHCS	TPS S-DARS CRA SWIS-CRA WxITC	Aviation Pilot Weather Education -Weather Strategies -Weather Tactics -Mountain Flying -Practical Weather -"Never Again" -SkySpotter Aviation Weather Hazards COMET NWA Internet Courses -Thunderstorms and Flying -Winter Weather and Flying		DA AWARE
Ground de-icing			NWA Internet Courses -Winter Weather and Flying		FDI

(continued)

TABLE 9. Aviation weather programs led by universities, industry, and associations (continued)

Service area	Weather product development	Weather product dissemination	Education, training, and outreach	Cockpit Display	Decision support systems & capabilities
In-flight icing	AWIN CRA3 AWHCS	TPS AWIN CRA AWIN CRA2 S-DARS CRA SWIS-CRA WxITC FISDL	Aviation Pilot Weather Education -Weather Strategies -Weather Tactics -Mountain Flying -Practical Weather -"Ne ver Again" -SkySpotter Aviation Weather Hazards COMET NWA Internet Courses -Thunderstorms and Flying -Winter Weather and Flying	WINN	DA AWARE WebASD
Terminal winds and temperatures	Hub-CAPS	TPS FISDL ADWSA	Aviation Pilot Weather Education -W eather Strategies -Weather Tactics -Mountain Flying -Practical Weather -"Never Again" -Operations at Towered Airports -SkySpotter Aviation Weather Hazards COMET EWINS NWA Internet Courses -Thunderstorms and Flying -Winter Weather and Flying		
Turbulence	AWIN CRA3 AWHCS	TPS AWIN CRA1 AWIN CRA2 S-DARS CRA SWIS-CRA WxITC FISDL VDLM2	Aviation Pilot Weather Education -Weather Strategies -Weather Tactics -Mountain Flying -Practical Weather -"Ne ver Again" -Operations at Towered Airports -SkySpotter Aviation Weather Hazards COMET NWA Internet Courses -Thunderstorms and Flying -Winter Weather and Flying	WINN	LIDAR DA AWARE EWxR WebASD
Volcanic ash		TPS	Volcanic Ash Avoidance		

LEGEND: Already implemented (FY 1997-2002)
In implementation now (FY 2003–04)
Future implementation planned or scheduled for FY 2004–07 time frame

Table 10. Aviation weather programs and projects

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
ADAS	AWOS Data Acquisition System	Dissemination	FAA	AUA 400		I	Collection of surface observations from multiple sites
ADDS	Aviation Digital Data Service	Development	FAA	AWRP	NOAA, NCAR	N	Provide aviation weather products via the Internet; operational fall 2003
ADWSA	Automatic Delivery of Wind Shear Alerts	Dissemination	Industry	Northwest Airlines	FAA	I	Provide wind shear alerts to the cockpit
AHAS	Airborne Hazard Awareness System	Decision support	NASA	WxAP		F	Improve pilot's situational awareness
AIP	Aircraft Icing Product	Development	NOAA	NESDIS		N	Depict areas of icing potential for hazard avoidance
ALDA	Airborne LIDAR Detection Algorithm	Decision support	NASA	AvSP	FAA	F	Improve in-flight turbulence detection
AMS	Automated Meteorological System	Decision support	DOD	Air Force		N	Automated observations
AOC	Aviation Operations Course	Ed/train/outreach	NOAA	NWS		N	Train forecasters to provide better operational aviation forecasts
AOS	Automated Observing System	Development	DOD	Air Force		N	Collect data from multiple locations
APWE	Aviation Pilot Weather Education	Ed/train/outreach	Association	AOPA/ASF		I	Provide training materials for general aviation pilots (courses listed in Table 11)
ASAP	Advanced Satellite Aviation Products	Development	NASA	WxAP	FAA	N/F	Incorporate satellite data in aviation weather products
ASOS	Automated Surface Observing System Upgrades	Development	NOAA	NWS	FAA, DOD	N	Incorporate ice-free wind sensor in existing ASOS; other upgrades
ATLAS	Aircraft Total Lightning Advisory System	Development	Industry	Airborne Research	Rockwell-Collins Corp.	F	Detect and map total lightning
AWARE	Aviation Weather Awareness and Reporting Enhancement	Decision support DOD	Industry	Rockwell	NASA, FAA, NOAA,	C	Improve pilot's situational awareness; capability to be incorporated in AHAS decision support system (NASA)
AWH	Aviation Weather Hazards	Ed/train/outreach	University	U. of Kansas		I	Training on weather hazards for pilots (courses listed in Table 11)
AWHCS	Aviation Weather Hazard Characterization System	Development	University	U. of Oklahoma/ CAPS	NCAR, FSL, MIT/ Lincoln Labs	N	Create a 3-dimensional database of atmospheric variables
AWIN	Aviation Weather Information	Decision support	NASA	WxAP	Industry	N/F	Optimize human factors in display of weather information
AWIN CRA1	Aviation Weather Information (Datalink)	Dissemination	Industry	Honeywell	NASA	C	Datalink graphical weather information to general aviation aircraft; incorporation in commercial products at lead entity's discretion
AWIN CRA2	Aviation Weather Information (Datalink)	Dissemination	Industry	ARNAV	NASA	C	VHF datalink graphical weather information to general aviation aircraft; incorporation in commercial products at lead entity's discretion
AWIN CRA3	Aviation Weather Information	Development	Industry	Honeywell	NASA	C	Optimize route selection for dispatchers; incorporation in commercial products at lead entity's discretion

(continued)

Table 10. Aviation weather programs and projects (continued)

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
AWIPS	Advanced Weather Interactive Processing System	Decision support	NOAA	NWS		I	Improved product generation, dissemination, and forecaster decision aid
C&V	Ceiling and Visibility	Development	DOD	Navy		N	Produce ceiling and visibility forecasts
CA	Circulation Algorithm	Development	FAA	AWRP		F	Detect storm circulations hazardous to aviation
Capstone	Alaskan Region Safe Flight 21	Decision support	FAA	AND-1	Air carriers in 2 Alaskan regions	I/N	Reduce accidents by providing traffic, terrain, and weather information to the cockpit via datalink technology
CCFP	Collaborative Convective Forecast Product	Decision support	NOAA	NWS	FAA, airline industry	I	Better forecasts of convective weather for traffic product management within NAS
CDFS II	Cloud Depiction and Forecast System	Development	DOD	Air Force		N	Produce cloud cover forecasts
CDMNET	Collaborative Decision Making Net	Dissemination	FAA	AUA		I	Dissemination of weather information to airline operation centers
CIP	Current Icing Potential	Development	FAA	AWRP		I	Depict areas of icing for in-flight avoidance
CIWS	Corridor Integrated Weather System	Decision support	FAA	AWRP		N	Regional convective nowcasts and forecasts for traffic management
COMET	Cooperative Program for Operational Meteorology, Education and Training	Ed/train/outreach	University	UCAR-NCAR	NOAA, AFWA, NMOC, NESDIS, MSC, NPOESS	I	Training modules for providers of aviation weather information (courses listed in Table 11)
DA	Divert Alerts	Decision support	Industry		Sonalysts, Inc.; United Airlines	I	Aid flight dispatch with diverted aircraft
DCAFS	Dallas-Fort Worth Collaborative Aviation Forecast Study	Decision support	NOAA	NWS		I	Improved TAFs for traffic management decision making
DLAC	Distance Learning Aviation Course	Ed/train/outreach	NOAA	NWS		N/F	Train providers on aviation weather hazards (courses listed in Table 11)
E&T Program	Education and Training	Ed/train/outreach	NASA	GRC		I	Provide pilot education on in-flight icing (courses listed in Table 11)
ESID	Electrical Storm Identification Device	Development	DOD	Navy		I	Lightning detection
EWINS	Enhanced Weather Information System Training	Ed/train/outreach	Industry	Northwest Airlines		I	Qualify meteorologists to write TAFs
EWxR	Enhanced Weather Radar	Decision support	Industry	Rockwell	NASA, FAA, NOAA, DOD	C	Extend range of airborne radar; capability to be incorporated in AHAS
FAA Acad.	FAA Academy Training	Ed/train/outreach	FAA			I	Courses listed in Table 11
FBWTG	FAA Bulk Weather Telecommunications Gateway	Dissemination	FAA			I	Dissemination of weather information to multiple users
FDI	Forecasting for De-Icing	Decision support	Industry	Northwest Airlines		I	Support de-icing decision making

(continued)

Table 10. Aviation weather programs and projects (continued)

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
FFP	Fog Forecasting Process	Development	Industry	UPS		I	Forecasting process for radiation fog
FIP	Forecast Icing Potential	Development	FAA	AWRP		N	Forecast areas of icing for in-flight avoidance
FISDL	Flight Information Services Data Link	Dissemination	FAA	AUA 460	Industry	I	Provide weather information to the cockpit of general aviation aircraft
GAF	Graphical Area Forecast	Development	NOAA	NWS		N	Graphical depiction of weather information for easier user interpretation
GIFTS	Geosynchronous Imaging Fourier Transform Spectrometer	Development	NASA	ESE	NOAA	F	High-resolution atmospheric soundings
GLDI	Global Lightning Data Integration	Development	Industry	Sonalysts		N	Integrate global lightning data with other data sets over remote areas
GRIDS	Ground-Based Remote Icing Detection System	Development	FAA	AWRP		F	Improve ground-based detection of in-flight icing
GTG	Graphical Turbulence Guidance	Development	FAA	AWRP	NOAA	N	Improve short-term turbulence forecasts above Flight Level 200
GTWAPS	Global Theater Weather Analysis and Prediction System	Development	DOD	Air Force		I	Produce visualization products
GWIS	Global Weather Information System	Decision support	FAA	AUA-400		F	Replacement for WARP
Hub-CAPS	Center for Analysis and Prediction of Storms	Development	Industry	American Airlines	U. of Oklahoma/ CAPS	I	Storm-scale forecasts supporting terminal operations
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectories	Development	NOAA	OAR/ARL		N	Improved volcanic ash dispersion forecasts for hazard avoidance
IHAS	Integrated Hazard Avoidance System	Decision support	Industry	Honeywell Bendix/King		I	Provide graphical information to the cockpit for decision support
IMETS	Integrated Meteorological System	Dissemination	DOD	Army		I	Dissemination of weather information
IP	Internet Protocol	Dissemination	FAA	ARS	NWS	I	Certify Internet weather providers
IRP	Icing Research Program	Decision support	DOD	Army	ERDC, CRREL, NASA, FAA, NCAR, NOAA	F	Detect in-flight icing
ITA	In-Situ Turbulence Algorithm	Development	FAA	AWRP		N	Measure and objectively report turbulence
ITWS	Integrated Terminal Weather System	Decision support	FAA	AUA 400		I	Ingrate terminal weather information from multiple sensors
JAWS	Juneau Airport Wind System	Development	FAA	AUA 400		N	Detect wind hazards at Juneau, Alaska, airport
LCP	Low Cloud Product	Development	NOAA	NESDIS		N	Safer operations in low clouds and reduced visibility conditions
LIDAR	Light Detection and Ranging	Decision support	NASA	WxAP	Industry	F	Early onboard detection of turbulence
LLWAS-NE	Low Level Windshear Alert System - Network Expansion	Decision support	FAA	ATB 420		I	Detect wind-shear at airports

(continued)

Table 10. Aviation weather programs and projects (continued)

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
LPATS	Lightning Position and Tracking System	Development	DOD	Navy		I	Lightning detection
MDCRS	Meteorological Data Collection and Reporting System	Development	FAA	AWRP	NWS	I	Observation input to numerical model forecasts
METMF (R)	Marine Corps Meteorological Mobile Facility Replacement	Development	DOD	Navy		N	Mobile facility for METOC support
MIAWS	Medium Intensity Airport Weather System	Decision support	FAA	ATB 420		I	Provide integrated weather information at smaller airports
MIDDS-T	Meteorological Integrated Data Display System - Tactical	Development	DOD	Navy		I	Produce full range of forecast products for tactical use
MMCR	Millimeter Cloud Radar	Development	NOAA	NWS		F	Detect and avoid areas of supercooled liquid droplets
MMS-P	Meteorological Measuring Set - Profiler	Decision support	DOD	Army		F	Provide profiles of winds and temperature
MRC	Multi-Radar Composites	Development	FAA	AWRP		F	Integrate multiple radars and algorithms
MRS	Mini Rawinsonde System	Development	DOD	Navy		I	Mobile upper air soundings
MSFS	Marine Stratus Forecast System	Decision support	FAA	AWRP		N	Maximize arrivals at airports affected by marine stratus
MWAVE	Mountain Wave	Development	NOAA	NWS		N	Reduce injuries by avoiding areas of terrain-induced turbulence
MWFM	Mountain Wave Forecast Model	Development	DOD	Navy		F	Produce small-scale turbulence forecasts
NAAPS	Navy Aerosol Analysis and Prediction System	Development	DOD	Navy		F	Produce visibility forecasts supporting tactical operations
NCV	National Ceiling and Visibility	Development	FAA	AWRP	Navy, NOAA, NCAR, MIT/Lincoln Labs	N	Improve en route ceiling forecasts for general aviation
NCWF	National Convective Weather Forecast	Development	FAA	AWRP	NCAR, NOAA	I	Improve convective SIGMET forecasts
NFWB	Navy Flight Weather Briefer	Dissemination	DOD	Navy		I	Provide Internet-based flight weather briefs
NITES	Naval Integrated Environmental Subsystem	Development	DOD	Navy		I	Forecast toolkit and data distribution
NLDN	National Lightning Detection Network	Development	NOAA	NWS	FAA, DOD	N	Improve detection and forecasting of convection
NSDS-E	Naval Satellite Display System - Enhanced	Development	DOD	Navy		I	Receive and process satellite data
NTDA	NEXRAD Turbulence Detection Algorithm	Development	FAA	AWRP		N	Ground-based detection of turbulence
NTFS	New Tactical Forecast System	Development	DOD	Air Force		I	Produce weather products supporting aviation
NWA	National Weather Association Internet	Ed/train/outreach	Association	NWA	Air Force, others	I	Courses listed in Table 11
NWSTC	National Weather Service Training Center	Ed/train/outreach	NOAA	NWSTC		N	Courses listed in Table 11
OACD	Oceanic Automated Convective Diagnosis Product	Development	FAA	AWRP		F	Provide the cockpit with updated convective weather information over oceanic areas

(continued)

Table 10. Aviation weather programs and projects (continued)

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
OACN	Oceanic Automated Convective Nowcast Product	Development	FAA	AWRP		F	Provide the cockpit with updated convective weather information over oceanic areas
OASIS	Operational and Supportability Implementation System	Decision support	FAA	AUA-400		I	Provide pilots with preflight and in-flight weather information
OCTH	Oceanic Cloud Top Height Product	Development	FAA	AWRP		N	Provide the cockpit with updated convective weather information over oceanic areas
OITFA	Oceanic Integrated Turbulence Forecast Algorithm	Development	FAA	AWRP		F	Provide the cockpit with updated turbulence information over oceanic areas
OPS II	Operational Weather Squadron Production System, Phase II	Dissemination	DOD	Air Force		I	Dissemination of aviation weather products
OPUP	Open Principal User Processor	Development	DOD	Air Force/ Navy		N/F	Graphical user interface for NEXRAD
PA	Polarization Algorithm	Development	FAA	AWRP		F	Detect hydrometeors hazardous to aviation
PCIS	PC-based Icing Simulator	Ed/train/outreach	NASA	SWAP		N	Provide training under simulated icing conditions
PTI	Pilot Training Initiative	Ed/train/outreach	NOAA	NWS		F	Improve pilot interpretation of aviation weather products
PUFF	Volcanic Ash Dispersion Model	Development	DOD	Air Force		I	Dispersion forecasts for volcanic ash
QTP	Qualification Training Packages	Ed/train/outreach	DOD	Air Force		I	Courses listed in Table 11
RADAR	Radio Detection and Ranging	Decision support	NASA	WxAP		N	Early onboard detection of turbulence using radar
RAWS	Remote Automated Weather Sensor	Decision support	DOD	Navy		I	Automated relocatable weather observations
RCWF	Regional Convective Weather Forecast	Development	FAA	AWRP		N	Extended forecasts of regional convection
RUC	Rapid Update Cycle Model	Development	NOAA	AWRP		I	Forecasts of smaller time and space scales or aviation weather hazards
RVR	Runway Visual Range	Decision support	FAA			I	Improve runway visual range reporting
SBID	Satellite-Based Icing Detection	Development	FAA	AWRP		I	Detection of in-flight icing; component of CIP & FIP
S-DARS	Satellite Digital Audio Radio Service (WINCOMM)	Dissemination	NASA		Industry	F	Provide high bandwidth satellite communications to aircraft
SMOOS (R)	Shipboard Meteorological and Oceanographic Observing System Replacement	Development	DOD	Navy		N	Automated weather observations
SVS	Synthetic vision systems	Decision support	NASA	AvSP	Industry, university	N	Enable safe flight under low ceiling and reduced visibility conditions
SWIS	Satellite Weather Information System (WINCOMM)	Dissemination	NASA		Industry	F	Graphical weather information to the cockpit via satellite datalink
SWR	Supplemental Weather Radar	Decision support	DOD	Navy		I	Remote weather radar
TAF	Terminal Aerodrome Forecast Improvements	Development	NOAA	NWS		N	Improve flight safety and efficiency within the NAS

(continued)

Table 10. Aviation weather programs and projects (continued)

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
TAM	Tactical Area Met	Development	DOD	NAVY		N	
TAMDAR	Tropospheric Airborne Meteorological Data Reporting	Development	NASA	WxAP		N	Increase number of airborne observations for model analyses and forecasts
TCV	Terminal Ceiling and Visibility	Development	FAA	AWRP		F	Improve ceiling and visibility forecasts for terminal area
TCWF	Terminal Convective Weather Forecast Product	Development	FAA	AWRP	MIT/ Lincoln Labs	N	Improve convective weather forecasts at high traffic density airports
TDWR	Terminal Doppler Weather Radar	Decision support	FAA	ATB 420		I	Detect wind hazards at large airports
TEDS	Tactical Environmental Data Services	Dissemination	DOD	Navy		I	Data assimilation and distribution
TEP	Tactical Environmental Processor	Decision support	DOD	Navy		N	Ship-based Doppler radar
TMOS	Tactical Meteorological Observing System	Decision support	DOD	Air Force		I	Automated observations
TPS	Turbulence Plot System	Dissemination	Industry	Northwest Airlines	ARINC	I	Provide text-formatted messages of weather hazards to commercial aircraft
TWR	Tactical Weather Radar	Decision support	DOD	Air Force		I	Improved radar observations
VAA	Volcanic Ash Avoidance	Ed/train/outreach	Industry	Boeing (producer)	ALPA (distributor)	I	Videotape to train pilots on ash avoidance
VAFTAD	Volcanic Ash Forecast Transport and Dispersion Model	Development	NOAA	OAR		I	Ash dispersion forecasts for hazard avoidance
VAG	Volcanic Ash Graphic	Development	NOAA	NWS	NCEP, ARL, NESDIS	N	Graphical volcanic ash advisory for hazard avoidance
VAP	Volcanic Ash Product	Development	NOAA	NESDIS		N	Improved detection of volcanic ash for aircraft avoidance
VAW	Volcanic Ash Warning	Development	FAA	AWRP		F	Avoid volcanic ash over oceanic areas
VDLM2	VHF Data Link Mode 2	Dissemination	Industry	ARINC		I	Air/ground datalink technology that delivers information at 31.5 kbps
WARP	Weather and Radar Processor	Decision support	FAA	AUA-400	NWS	I	Provide en route weather information for traffic management
WebASD	Web-based Aircraft Situation Display	Decision support	Industry	ARINC		I	Graphical display of hazardous weather conditions
WGPP	Wind Gust Potential Product	Development	NOAA	NESDIS		N	Warn of dangerous wind conditions
WINCOMM	Weather Information Communications	Dissemination	NASA	WxAP	FAA, NOAA, DOD	I	Transmit graphical weather information to the cockpit
WINN	Weather Information Network	Cockpit display	Industry	Honeywell		N	Cockpit display capability for weather information
WMSCR	Weather Message Switching Center Replacement	Decision support	FAA			I	Improve dissemination of weather information
WRF	Weather Research and Forecasting Model	Development	NOAA		NCAR, FAA, NSF, AFWA, Navy, U. of Oklahoma/CAPS, others	N/F	Smaller scale resolution in forecasts of aircraft impact variables now; continuing future improvements in forecasts of aviation weather hazards at storm scale to continental scale

(continued)

TABLE 10. Aviation weather programs and projects (continued)

Acronym	Name	Main product[a]	Lead entity[b]	Lead office[b]	Partners	Status[c]	User benefit
WSDDM	Weather Support to De-Icing Decision Making	Decision support	FAA	AWRP	NCAR	I	Improve safety for de-icing operations
WSP	Weather System Processor (ASR-9)	Decision support	FAA	ATB-420		I	Detect wind hazards in terminal area
WVSS	Water Vapor Sensing System	Development	FAA	AWRP	NOAA, NCAR, airlines	I	Provide moisture input to numerical models
WxITC	Weather-in-the-Cockpit	Dissemination	Industry	Sonalysts, Jeppeson	NASA, NCAR, NWS/ AWC, airlines	I	Weather information integration and dissemination to commercial aircraft

[a]Main product types are abbreviated as follows: Development = weather observation/forecast product; Dissemination = weather product dissemination; Ed/train/outreach = education, training, and outreach; Cockpit display = cockpit display system; Decision support = decision support system or capability.

[b]The lead entity corresponds to the program matrix (Tables 5-9) in which the program is shown. Where a federal agency is the lead entity, the lead office is the organizational division within that agency with program responsibility. If the lead entity is an industry, university, or association, the lead office column provides its name.

[c]This column indicates when the program's main product(s) will be implemented and available to end users:
I = already implemented (FY 1997-2002)
N = in implementation now (FY 2003-04)
C = research under a CRA has been completed; product implementation is under way or at discretion of the industry partner
F = future implementation planned or scheduled for FY 2004-07 time frame

TABLE 11. Aviation weather education and training programs

Lead entity	Program name	Course	Status[a]
AOPA (association)	Aviation Pilot Weather Education	Weather Strategies Seminar	I
		Weather Tactics Seminar	I
		Mountain Flying Seminar	I
		Practical Weather Seminar	I
		"Never Again" Seminar	I
		Operations at Towered Airports Seminar	I
		SkySpotter	I
NWA (association)	National Weather Association Internet Courses	Thunderstorms and Flying	I
		Winter Weather and Flying	I
DOD/AF	Qualification Training Packages	Icing Qualification Training Package	I
		Turbulence Qualification Training Package	I
		Convection Qualification Training Package	I
		Metwatch Qualification Training Package	I
		Flight Weather Brief Qualification Training Package	I
		Volcanic Ash Computer Based Training Module	I
		WSR-88D PUP Operator/Manager Course	I
		Weather Elements Qualification Training Package	I
FAA	FAA Academy Training	Ground De-Icing, Anti-Icing Operations	I
		Low-Level Windshear Alert System	I
		In-Flight Icing	I
		ASOS	I
		METAR/TAF	I
		Basic Aviation Weather	I
		Wake Turbulence	I
		Low-Level Wind Shear/Microburst Alerts	I
		Weather System Processor	I
		Integrated Terminal Weather System	I
		Automated Weather Sensors System	I
		Severe Weather	I
Boeing (industry)	Volcanic Ash Avoidance		I
NASA	Aircraft Operations Systems/ Education and Training Program	Icing for General Aviation Pilots (video)	I
		Tailplane Icing (video)	I
		Icing for Regional and Corporate Pilots (video)	I
		A Pilot's Guide to In-Flight Icing (computer-based training)	I
NASA	SWAP	PC-based Icing Simulator	N
NOAA	NWS Training Center Courses	Forecasting Turbulence	N
		Forecasting Icing	N
		Forecasting Low Level Clouds/Fog for Aviation Ops	N
		Low Level Wind Shear	N
		Severe Convection Forecasting and Warnings	N
NOAA	NWS Aviation Operations Course		F
NOAA	NWS Distance Learning Aviation Course	Forecasting Fog and Stratus	N
		Convective Forecasting	F
NOAA	NWS Pilot Training Initiative		F
Kansas (univ.)	Aviation Weather Hazards		I
UCAR-NCAR (university)	Cooperative Program for Operational Meteorology, Education and Training (COMET)	Clouds, Snow, and Ice Using MODIS	I
		Forecasting Icing Type and Severity	I
		Forecasting Radiation Fog	I
		Icing Assessment Using Observations and Pilot Reports	I
		Icing Assessment Using Soundings and Wind Profiles	I
		Radiation Fog	I
		Review of GOES Infrared Imagery Including Winter and Icing Applications	I
		West Coast Fog	I
		Gap Winds	I
		Thermally Forced Circulation 1: Sea Breezes	I
		Thermally Forced Circulation 2: Mountain/Valley Breezes	I
		Forecasting Aviation Icing: Icing Event of 6 March 1996	I

[a]I = already implemented (FY 1997-2002)
N = in implementation now (FY 2003-04)
F = future implementation planned or scheduled for FY 2004-07 time frame

5

Conclusions and Recommendations

The first five conclusions from the mid-course assessment are based on the trends in accident rates discussed in Sections 2 and 3, plus the portfolio review of projects related to the risks from Section 4. The final conclusion and recommendation relate to the entire portfolio, including programs that either provide indirect support to the specific accident reduction objectives or support other objectives of the *National Aviation Weather Program Strategic Plan*.

Accident Risk Reduction Actions

The NTSB weather factor citations for Part 91 aircraft (general aviation) show strong downward trends. If the trends hold, the citation rates for fatal weather-related accidents will meet or exceed the benchmark goal of an 80 percent reduction for this aviation category. The reduction goal can even be met within most of the weather hazard categories. The portfolio analysis indicates that a combination of factors has contributed to this good news, including products and services from the National Weather Service Modernization, aviation-specific products and systems from R&D sponsored by the FAA's Aviation Weather Research Program, and better information dissemination systems and services. Particularly important for general aviation has been the knowledge pilots have gained, through education and training opportunities, in how to use the information that these technological advances are making available.

The aim should be to provide every general aviation pilot with knowledge of all weather hazards the pilot is likely to encounter…

Conclusion 1. The partnerships through which aviation and weather associations, the aviation industry, and federal agencies have provided education, training, and outreach to the general aviation community have made a strong beginning in reducing the risks of weather-related accidents in the Part 91 aircraft regulatory category. The ambitious goal of an 80 percent reduction in the fatal accident rate for general aviation appears attainable by 2006 if these efforts can be expanded to reach every general aviation pilot. The general aviation community will also need to know about new products and services that are becoming available, such as those resulting from university-based R&D. The development and implementation programs for these new products and services must be sustained, despite fiscal constraints and tight budgets.

Recommendation 1. The partnerships for education, training, and outreach should be expanded to include more collaboration among entities offering courses and materials. The aim should be to provide every general aviation pilot with knowledge of all weather hazards that the pilot is likely to encounter, together with the information and advisory services to deal with them safely. To sustain the accident reduction trends, these education and outreach efforts must keep pilots informed about the new products and services emerging from R&D to the implementation phase.

The accident trends for Part 135 aviation differ from the trends for both the general aviation community regulated under FAR Part 91 and the major commercial carriers regulated under FAR Part 121. Many of the data series for annual weather factor citation rates, even when aggregated into hazard categories, display considerable year-to-year variability. Nonetheless, only in two categories do the linear regression trends indicate that an 80 percent reduction in fatal accident rates will be achieved by 2006. A particular concern is that Part 135 trends are flat or even increasing for several weather hazard categories. The data series for all weather-related accidents in each hazard category confirm the indications that aircraft regulated under Part 135 are not experiencing the risk reductions occurring for aircraft under Parts 91 and 121. A number of factors appear to make this aircraft category different, although the actual contribution of each factor cannot be assessed from the data available for this report.

The technology exists to lower weather-related risks for Part 135 operations… A more detailed analysis is needed to assess the impact of weather hazards on this aviation community.

Conclusion 2. Part 135 aviation is constrained by factors that distinguish it from either general aviation or major commercial carriers. The range of operations and types of services offered in this category vary widely and include some that are inherently more hazardous than general aviation or commercial air carrier flights. Early results from the Alaskan Region Capstone demonstration, part of the FAA's Safe Flight 21 program, indicate that the technology exists to lower weather-related accident risks for at least some Part 135 operations. Unfortunately, the current deployment schedule for Safe Flight 21 will not provide weather information coverage across most of the National Airspace System until the 2007–12 time frame. A more detailed analysis of weather-related accidents involving Part 135 aircraft will be needed to determine how different segments of this diverse category are affected by various weather hazards and what actions could be taken to lessen the risks and reduce accident rates.

Recommendation 2. A more detailed analysis, probably employing a case analysis approach, should be conducted to assess the impact of weather hazards on specific segments of the aviation community regulated under Part 135. As an interim measure, a special effort should be made to ensure that both pilots and owners of Part 135 aircraft are aware of the weather information infrastructure and services available to them.

- Prior to deployment of Flight Information Services–Broadcast under the Safe Flight 21 program, available information sources and services, such as the Aviation Digital Data Service and the Flight Information Services Data Link, can be emphasized in the outreach program.
- As the Flight Information Services–Broadcast becomes available via the Safe Flight 21 Universal Access Transceiver communications uplink, training in this information service should be emphasized.

Turbulence and convection hazards continue to be cited as factors in the majority of weather-related accidents involving major air carriers (Part 121 aviation). Fortunately, these accidents now rarely result in fatalities. Fatal accidents involving this weather hazard category are decreasing for Part 91 and Part 135 aviation, but the rates for both fatal and total accidents make this weather hazard category a continuing concern.

Conclusion 3. No single sensor system or forecast improvement will address the entire range of conditions, both en route and in the terminal area, that produce turbulence and convection hazards. Nevertheless, a sustained effort can put new technology in place, assess its effectiveness, and ensure full implementation of products and services with proven efficacy. A number of programs that are likely to improve detection, forecast, and warnings about these hazards are in or nearing the implementation stage.

Recommendation 3. Investment should continue in R&D and implementation on projects that will contribute to timely observations, forecasts, and warnings of turbulence and convection phenomena, both en route and near the terminal area.

High density altitude can be addressed if the pilot has the correct information and the tools and training to use it.

For the period reviewed for this assessment (1996 through 2001), high density altitude has been the most frequently cited factor in the category of temperature and lift hazards for general aviation and Part 135 carriers. Multiple factors of altitude (elevation of the takeoff or landing site), temperature, and humidity interact to complicate a pilot's calculation of the correct density altitude. The pilot needs accurate data on conditions (temperature and humidity) for the location (elevation) and time at which the aircraft will be in a situation where density altitude could adversely affect a flight maneuver. The pilot must then consider the performance consequences for a specific airframe, engine characteristics, and load (weight and trim).

Conclusion 4. The hazard of high density altitude can be addressed, if the pilot has accurate observations or forecasts and a decision support tool that receives this information and combines it with the specifications and running condition of the aircraft. The pilot must also have the training to understand the implications of advice or guidance provided by this decision support capability.

The aviation R&D efforts undertaken jointly by partnerships of federal agencies, industry, universities, and associations have produced substantial returns on the federal investment.

Recommendation 4. A review should be undertaken of the circumstances contributing to aviation accidents in which the National Transportation Safety Board has cited high density altitude as a factor. This review should assess the tools currently available to Part 91 and Part 135 pilots to assess density altitude and related aircraft performance parameters, as well as the weather information products, decision support capabilities, or education and training resources that could be provided or improved to reduce the risk from this weather hazard.

The strong downward trends for fatal and total weather-related general aviation accidents in most weather hazard categories, as well as the continued progress in reducing weather-related accidents involving the major carriers (Part 121 aviation), provide evidence that the national aviation weather initiatives are producing results. However, the fatal accident trends have not yet achieved the 80 percent reduction goal set in 1997. Most of the weather factors that continue to cause fatal accidents can be further ameliorated by programs and projects that are ready for implementation now or will be in the next few years. Examples discussed in this report include fog and low ceiling, in the ceiling and visibility service area, and terminal area winds.

Conclusion 5. Curtailment or delays in implementation of useful new products, services, and systems could jeopardize achievements in accident reduction that seem within reach if we stay the course. Continued support is essential for these efforts, which are nearing the point of producing real returns and achieving a national safety priority.

Recommendation 5. Investment should be sustained for aviation weather projects and programs whose results are likely to further reduce the risks from weather hazards that continue to be cited in aviation accidents. All the partners whose joint efforts in the past have made possible the progress documented in this assessment must continue their commitments and strengthen their collaborations.

The benefits of aviation weather R&D are passed on to passengers and consumers as increased safety and improved efficiency and access. Photo courtesy Wings of Alaska Airlines, © Fred Hirschmann.

Conclusion on the General Status of the Portfolio

Many of the projects listed in Table 10 are now, or soon will be, contributing to the safety and efficiency of the National Airspace System. The highlights from the five product areas—weather product development; weather product dissemination; education, training, and outreach; cockpit displays; and decision support systems and capabilities—illustrate how projects and initiatives in each area complement and leverage one another. New weather information products must be disseminated to end users who have been trained to use them correctly. As the information available increases, well-designed human-machine interfaces are necessary to convey the right information at the right time without distraction or confusion. Decision support capabilities and systems can integrate and interpret these multiple data items into a coherent "situational awareness" for the user.

The President's Council of Advisors on Science and Technology issued a report in October 2002 on "Assessing the U.S. R&D Investment." The council's third recommendation was that the Office of Science and Technology Policy, in cooperation with the appropriate agencies and organizations, "should assess and analyze the adequacy of federal R&D investments in light of national interests, international competition, and human resource needs." The composite structure of aviation weather R&D efforts, undertaken jointly by partnerships among federal agencies, industry, universities, and aviation-interested associations, meets this performance test of producing substantial returns on the federal R&D investment.

Curtailment or delays in implementing useful products, services and systems could jeopardize accident reductions that seem within reach if we stay the course.

Conclusion 6. The combined and complementary effects of implemented aviation weather R&D have produced substantial and continuing benefits for the entire aviation industry. Those benefits are passed on to passengers and consumers as increased safety during air travel and improved efficiency and access in the air transport of passengers and cargo. To continue the promising trends—and to overcome the remaining challenges—in reducing weather-related aviation risks identified in this assessment will require sustaining the R&D and implementation programs in progress.

Recommendation 6. The investments in national aviation weather programs and initiatives should be supported and promoted as an effective investment in the nation's future.

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Appendix A

NTSB Weather Factor Citation Data 1995–2001

Note: The citation frequencies in these tables were calculated using the annual estimates of flight-hours (Parts 91 and 135) or departures (Part 121) from Table 1. These estimates are shown at the bottom of each table.

Table A-1. Part 91 (general aviation) weather factor trend analysis: factor citations, all weather-related accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
A. Restricted visibility and ceiling hazards								
Below approach/landing minimums	3	10	3		2	5	1	24
Clouds	16	16	17	22	16	12	4	103
Fog	45	37	35	29	16	25	16	203
Haze/smoke	7	3	6	4	1	2	3	26
Low ceiling	59	45	52	41	34	36	19	286
Obscuration	8	7	8	12	10	8	3	56
Whiteout	2			1	1	1	3	8
Total hazard category citations	140	118	121	109	80	89	49	706
Frequency per 100,000 flight-hours[a]	0.56	0.47	0.47	0.43	0.27	0.31	0.18	0.38
2006 goal	0.10							
2006 projection	0.00							
B. Precipitation (non-icing) hazards								
Rain	11	7	13	9	9	5	6	60
Snow	17	11	9	6	7	17	8	75
Drizzle/mist	1	4	1	3	3	3	3	18
Total hazard category citations	29	22	23	18	19	25	17	153
Frequency per 100,000 flight-hours[a]	0.116	0.088	0.090	0.071	0.064	0.086	0.062	0.082
2006 goal	0.020							
2006 projection	0.027							
C. Icing conditions								
Icing conditions	25	18	11	9	13	9	3	88
Ice fog							1	1
Freezing rain	1		1	2		2	1	7
Carburetor icing conditions	28	17	24	26	18	18	17	148
Total hazard category citations	54	35	36	37	31	29	22	244
Frequency per 100,000 flight-hours[a]	0.217	0.141	0.141	0.145	0.104	0.100	0.080	0.130
2006 goal	0.036							
2006 projection	0.000							
D. Turbulence and convection hazards								
Turbulence (thunderstorms)	1	5	3	2		1		12
Thunderstorm	13	12	3	3	7	5	3	46
Thunderstorm (outflow)	3	1	2				1	7
Microburst/dry	1			1	1		1	4
Microburst/wet	1							1
Updraft				1	1	1	1	4
Downdraft	30	22	12	16	23	21	11	135
Gusts	74	105	87	75	74	51	62	528
Wind shear	8	9	1	6	8	9	5	46
Dust devil/whirlwind	3	5	2	1	9	4	6	30
Variable wind	6	11	5	10	9	9	12	62
Sudden wind shift	11	6	8	12	12	6	6	61
Mountain wave	2	1	2	3	1	1		10
Turbulence	13	10	7	9	13	4	3	59
Turbulence, clear air		3	1	2		1		7
Turbulence in clouds		1	1	2	1	2		7
Turbulence (terrain induced)	6	5	5	6	1	5	1	29
Total hazard category citations	172	196	139	149	160	120	112	1,048
Frequency per 100,000 flight-hours[a]	0.691	0.788	0.543	0.584	0.538	0.413	0.408	0.560
2006 goal	0.15							
2006 projection	0.11							

(continued)

Table A-1. Part 91 (general aviation) weather factor trend analysis: factor citations, all weather-related accidents (continued)

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
E. Temperature and lift hazards								
Temperature inversion							1	1
High density altitude	25	36	33	37	48	29	15	223
Temperature, high	3	4	5		1	1	1	15
Temperature, low	2				1	1		4
Thermal lift		1	1				3	5
No thermal lift	4	4	2	4	5	2	2	23
Total hazard category citations	34	45	41	41	55	33	22	271
Frequency per 100,000 flight-hours[a]	0.137	0.181	0.160	0.161	0.185	0.114	0.080	0.14
2006 goal	0.032							
2006 projection	0.066							
F. En route and terminal winds								
Unfavorable wind	20	14	17	7	6	7	1	72
Crosswind	90	123	111	87	78	80	77	646
Tail wind	50	36	36	46	46	52	41	307
High wind	18	36	17	19	12	14	20	136
Total hazard category citations	178	209	181	159	142	153	139	1,161
Frequency per 100,000 flight-hours[a]	0.71	0.84	0.71	0.62	0.48	0.53	0.51	0.62
2006 goal	0.16							
2006 projection	0.20							
G. Electrical hazards								
Lightning	1				1	1		3
Static discharge		1						1
Total hazard category citations	1	1	0	0	1	1	0	4
Frequency per 100,000 flight-hours[a]	0.004	0.004	0.000	0.000	0.003	0.003	0.000	0.002
2006 goal	0.0008							
2006 projection	0.0000							
H. Airborne solids hazards								
Sand/dust storm	1							1
Hail		2			1			3
Total hazard category citations	1	2	0	0	1	0	0	4
Frequency per 100,000 flight-hours[a]	0.004	0.008	0.000	0.000	0.003	0.000	0.000	0.002
2006 goal	0.001							
2006 projection	0.000							

[a]FAA estimated flight-hours per year:

1995	24,906,000
1996	24,881,000
1997	25,591,000
1998	25,518,000
1999	29,713,000
2000	29,057,000
2001	27,451,000

Table A-2. Part 91 (general aviation) weather factor trend analysis: factor citations, weather-related fatal accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
A. Restricted visibility and ceiling hazards								
Below approach/landing minimums	2	4			1	4		11
Clouds	14	11		16	11	10	3	65
Fog	34	30	22	22	9	15	11	143
Haze/smoke	3		3	2		1	2	11
Low ceiling	47	34	36	33	23	27	13	213
Obscuration	5	5	8	8	8	6	3	43
Whiteout						1		1
Total hazard category citations	105	84	69	81	52	64	32	487
Frequency per 100,000 flight-hours[a]	0.42	0.34	0.27	0.32	0.18	0.22	0.12	0.260
2006 goal	0.08							
2006 projection	0.00							
B. Precipitation (non-icing) hazards								
Rain	3	6	9	7	5	2	3	35
Snow	13	8	6	5	2	9	4	47
Drizzle/mist	1	2	1	2	3	2	2	13
Total hazard category citations	17	16	16	14	10	13	9	95
Frequency per 100,000 flight-hours[a]	0.068	0.064	0.063	0.055	0.034	0.045	0.033	0.051
2006 goal	0.013							
2006 projection	0.002							
C. Icing conditions								
Icing conditions	14	11	4	5	6	4		44
Ice fog							1	1
Freezing rain	1			2		1		4
Carburetor icing conditions	1	1	4	1		2	1	10
Total hazard category citations	16	12	8	8	6	7	2	59
Frequency per 100,000 flight-hours[a]	0.064	0.048	0.031	0.031	0.020	0.024	0.007	0.032
2006 goal	0.011							
2006 projection	0.000							
D. Turbulence and convection hazards								
Turbulence (thunderstorms)	1	4	2	2		1		10
Thunderstorm	8	8	3	2	6	3	3	33
Thunderstorm (outflow)	1							1
Microburst/dry	0							0
Microburst/wet	1							1
Updraft								0
Downdraft	3	2	1	1	2	1	2	12
Gusts	5	9	9	7	2	3	3	38
Wind shear		1		2		4		7
Dust devil/whirlwind	1							1
Variable wind					1			1
Sudden wind shift				1		1		2
Mountain wave	1	1	2	1	1			6
Turbulence	4	3	4	3	4	2	1	21
Turbulence, clear air		1		1				2
Turbulence in clouds		1		2	1	1		5
Turbulence (terrain induced)	3	3	2	4	1	1		14
Total hazard category citations	28	33	23	26	18	17	9	154
Frequency per 100,000 flight-hours[a]	0.11	0.13	0.090	0.102	0.061	0.059	0.03	0.082
2006 goal	0.02							
2006 projection	0.00							

(continued)

Table A-2. Part 91 (general aviation) weather factor trend analysis: factor citations, weather-related fatal accidents (continued)

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
E. Temperature and lift hazards								
Temperature inversion								0
High density altitude	3	9	10	8	9	6	2	47
Temperature, high						1		1
Temperature, low	1							1
Thermal lift								0
No thermal lift		1				1		2
Total hazard category citations	4	10	10	8	9	8	2	51
Frequency per 100,000 flight-hours[a]	0.016	0.040	0.039	0.031	0.030	0.028	0.007	0.027
2006 goal	0.006							
2006 projection	0.010							
F. En route and terminal winds								
Unfavorable wind	2	2	1					5
Crosswind	5	7		1	1			14
Tail wind	6	7	2	6	2	7	3	33
High wind	2	7	5	2	1	3	2	22
Total hazard category citations	15	23	8	9	4	10	5	74
Frequency per 100,000 flight-hours[a]	0.060	0.092	0.031	0.035	0.013	0.034	0.018	0.040
2006 goal	0.015							
2006 projection	0.000							
G. Electrical hazards								
Lightning	1				1	1		3
Static discharge		1						1
Total hazard category citations	1	1	0	0	1	1	0	4
Frequency per 100,000 flight-hours[a]	0.004	0.004	0.000	0.000	0.003	0.003	0.000	0.002
2006 goal	0.0008							
2006 projection	0.0000							
H. Airborne solids hazards								
Sand/dust storm	1							1
Hail		1			1			2
Total hazard category citations	1	1	0	0	1	0	0	3
Frequency per 100,000 flight-hours[a]	0.004	0.004	0.000	0.000	0.003	0.000	0.000	0.002
2006 goal	0.001							
2006 projection	0.000							

[a]FAA estimated flight-hours per year:

1995	24,906,000
1996	24,881,000
1997	25,591,000
1998	25,518,000
1999	29,713,000
2000	29,057,000
2001	27,451,000

Table A-3. Part 121 (major commercial carrier) weather factor trend analysis: factor citations, all weather-related accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
All factors	11	13	20	10	10	16	10	89
Frequency per 100,000 departures[a]	0.130	0.158	0.194	0.091	0.088	0.140	0.099	0.126
2006 goal	0.029							
2006 projection	0.062							
A. Restricted visibility and ceiling hazards								
Fog		1						1
Low ceiling							1	1
Whiteout			1					1
Total hazard category citations	0	1	1	0	0	0	1	3
B. Precipitation (non-icing) hazards								
Rain		1	1					2
Snow			1					1
Drizzle/mist				1				1
Total hazard category citations	0	1	2	1	0	0	0	4
C. Icing conditions								
Icing conditions			1					
Total hazard category citations	0	0	1	0	0	0	0	1
D. Turbulence and convection hazards								
Turbulence (thunderstorms)		1	1	3			2	7
Turbulence, convection induced						1	1	2
Gusts						1		1
Wind shear	1					1		2
Mountain wave						1		1
Turbulence	5	1	3	1	5	6	3	24
Turbulence, clear air	3	7	7	2	3	2		24
Turbulence in clouds	1		2	1	1	3	2	10
Total hazard category citations	10	9	13	7	9	15	8	71
Frequency per 100,000 flight-hours[a]	0.118	0.109	0.126	0.064	0.080	0.131	0.079	0.100
2006 goal	0.023							
2006 projection	0.067							
E. Temperature and lift hazards								
Temperature, high		1					1	2
Total hazard category citations	0	1	0	0	0	0	1	2
F. En route and terminal winds								
Unfavorable wind	1			1				2
Crosswind		1	2			1		4
Total hazard category citations	1	1	2	1	0	1	0	6
H. Airborne solids hazards								
Hail				1				1
Total hazard category citations	0	0	0	1	0	0	0	1
I. Other			1		1			2
Total hazard category citations	0	0	1	0	1	0	0	2

[a]FAA estimates of departures by year:

1995	8,457,465
1996	8,228,810
1997	10,318,383
1998	10,979,762
1999	11,308,762
2000	11,457,812
2001	10,082,023
2002	10,400,000

TABLE A-4. Part 121 (major commercial carrier) weather factor trend analysis: factor citations, weather-related fatal accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
All factors	0	0	1	0	0	0	1	2
Frequency per 100,000 departures[a]	0.000	0.000	0.010	0.000	0.000	0.000	0.010	0.003
2006 goal	0.000							
A. Restricted visibility and ceiling hazards								
Fog								0
Low ceiling								0
Whiteout								0
Total hazard category citations	0	0	0	0	0	0	0	0
B. Precipitation (non-icing) hazards								
Rain								0
Snow								0
Drizzle/mist								0
Total hazard category citations	0	0	0	0	0	0	0	0
C. Icing conditions								
Icing conditions								
Total hazard category citations	0	0	0	0	0	0	0	0
D. Turbulence and convection hazards								
Turbulence (thunderstorms)								0
Turbulence, convection induced								0
Gusts								0
Wind shear								0
Mountain wave								0
Turbulence								0
Turbulence, clear air			1					1
Turbulence in clouds								0
Total hazard category citations	0	0	1	0	0	0	0	1
Frequency per 100,000 flight-hours[a]	0.000	0.000	0.010	0.000	0.000	0.000	0.000	0.001
2006 goal	0.000							
E. Temperature and lift hazards								
Temperature, high							1	1
Total hazard category citations	0	0	0	0	0	0	1	1
F. En route and terminal winds								
Unfavorable wind								0
Crosswind								0
Total hazard category citations	0	0	0	0	0	0	0	0
H. Airborne solids hazards								
Hail								0
Total hazard category citations	0	0	0	0	0	0	0	0
I. Other								0
Total hazard category citations	0	0	0	0	0	0	0	0

[a]FAA estimates of departures by year:

1995	8,457,465
1996	8,228,810
1997	10,318,383
1998	10,979,762
1999	11,308,762
2000	11,457,812
2001	10,082,023
2002	10,400,000

Table A-5. Part 135 (smaller aircraft in revenue service) weather factor trend analysis: factor citations, all weather-related accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
A. Restricted visibility and ceiling hazards								
Below approach/landing minimums							1	1
Clouds	2	1	3	2		2	2	12
Fog	5	9	6	3	1	3	1	28
Low ceiling	7	10	9	6	5	7	3	47
Obscuration	2	2	2					6
Whiteout	1	3	2	3	4	3	1	17
Total hazard category citations	17	25	22	14	10	15	8	111
Frequency per 100,000 flight-hours[a]	0.33	0.42	0.54	0.34	0.27	0.38	0.23	0.41
2006 goal	0.075							
2006 projection	0.18							
B. Precipitation (non-icing) hazards								
Rain	2		1	2		1	2	8
Snow	2	2	2	2	3	4	1	16
Drizzle/mist	1	1						2
Total hazard category citations	5	3	3	4	3	5	3	26
Frequency per 100,000 flight-hours[a]	0.10	0.05	0.07	0.10	0.08	0.13	0.09	0.077
2006 goal	0.015							
2006 projection	0.12							
C. Icing conditions								
Icing conditions	4	3	4	4	3	3	2	23
Freezing rain	1				1	1		3
Carburetor icing conditions			1			2		3
Total hazard category citations	5	3	5	4	4	6	2	29
Frequency per 100,000 flight-hours[a]	0.10	0.05	0.12	0.10	0.11	0.15	0.06	0.09
2006 goal	0.015							
2006 projection	0.12							
D. Turbulence and convection hazards								
Turbulence (thunderstorms)						1		1
Thunderstorm				1				1
Downdraft	2	1	5	2	3			13
Gusts	4	3	2	3	2		2	16
Variable wind	1	1					1	3
Turbulence					1	1	1	3
Turbulence in clouds	1							1
Turbulence (terrain induced)	1		2			1	1	5
Total hazard category citations	9	5	9	6	6	3	5	43
Frequency per 100,000 flight-hours[a]	0.18	0.08	0.22	0.14	0.16	0.08	0.14	0.13
2006 goal	0.026							
2006 projection	0.10							

(continued)

Table A-5. Part 135 (smaller aircraft in revenue service) weather factor trend analysis: factor citations, all weather-related accidents (continued)

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
E. Temperature and lift hazards								
High density altitude	1		2	3	1	3		10
Temperature, low				1				1
Total hazard category citations	1	0	2	4	1	3	0	11
Frequency per 100,000 flight-hours[a]	0.02	0.00	0.05	0.10	0.03	0.08	0.00	0.03
2006 goal	0.002							
2006 projection	0.059							
F. En route and terminal winds								
Unfavorable wind	1	1	1		1	2		6
Crosswind		5	4	5	1	3	3	21
High wind	2	1	2	1	1		1	8
Tail wind		4	4	3	4	2	1	18
Total hazard category citations	3	11	11	9	7	7	5	53
Frequency per 100,000 flight-hours[a]	0.059	0.18	0.27	0.22	0.19	0.18	0.14	0.16
2006 goal	0.024							
2006 projection	0.23							
G. Electrical hazards								
Lightning	1							1
Total hazard category citations	1	0	0	0	0	0	0	1
Frequency per 100,000 flight-hours[a]	0.020	0.000	0.000	0.000	0.000	0.000	0.000	0.003
2006 goal	0.002							
2006 projection	0.00							

[a]FAA estimated flight-hours per year:

1995	5,113,866
1996	5,976,755
1997	4,080,764
1998	4,155,670
1999	3,640,731
2000	3,922,535
2001	3,476,432

Table A-6. Part 135 (smaller aircraft in revenue service) weather factor trend analysis: factor citations, weather-related fatal accidents

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
A. Restricted visibility and ceiling hazards								
Below approach/landing minimums								0
Clouds	2	1	3	2		1	1	10
Fog	3	2	2	2	1	2		12
Low ceiling	6	5	4	1	2	5	3	26
Obscuration	2	1						3
Whiteout			1		1	1	1	4
Total hazard category citations	13	9	10	5	4	9	5	55
Frequency per 100,000 flight-hours[a]	0.25	0.15	0.25	0.12	0.11	0.23	0.14	0.181
2006 goal	0.04							
2006 projection	0.09							
B. Precipitation (non-icing) hazards								
Rain	1			1		1		3
Snow	1			2	1	1	1	6
Drizzle/mist		1						1
Total hazard category citations	2	1	0	3	1	2	1	10
Frequency per 100,000 flight-hours[a]	0.04	0.02	0.00	0.07	0.03	0.05	0.03	0.033
2006 goal	0.006							
2006 projection	0.05							
C. Icing conditions								
Icing conditions	1	1	2	2	1	2	2	11
Freezing rain								0
Carburetor icing conditions								
Total hazard category citations	1	1	2	2	1	2	2	11
Frequency per 100,000 flight-hours[a]	0.02	0.02	0.05	0.05	0.03	0.05	0.06	0.036
2006 goal	0.004							
2006 projection	0.08							
D. Turbulence and convection hazards								
Turbulence (thunderstorms)						1		1
Thunderstorm								0
Downdraft	1		1					2
Gusts		1						1
Variable wind								0
Turbulence								0
Turbulence in clouds	1							1
Turbulence (terrain induced)	1		1					2
Total hazard category citations	3	1	2	0	0	1	0	7
Frequency per 100,000 flight-hours[a]	0.06	0.02	0.05	0.00	0.00	0.03	0.00	0.023
2006 goal	0.008							
2006 projection	0.00							

(continued)

Table A-6. Part 135 (smaller aircraft in revenue service) weather factor trend analysis: factor citations, weather-related fatal accidents (continued)

Hazard category and weather factor	1995	1996	1997	1998	1999	2000	2001	Total
E. Temperature and lift hazards								
High density altitude	1				1			2
Temperature, low				1				1
Total hazard category citations	1	0	0	1	1	0	0	3
Frequency per 100,000 flight-hours[a]	0.02	0.00	0.00	0.02	0.03	0.00	0.00	0.01
2006 goal	0.0020							
2006 projection	0.0012							
F. En route and terminal winds								
Unfavorable wind								0
Crosswind								0
High wind	1	1	1	1				4
Tail wind		1						1
Total hazard category citations	1	2	1	1	0	0	0	5
Frequency per 100,000 flight-hours[a]	0.02	0.03	0.02	0.02	0.00	0.00	0.00	0.02
2006 goal	0.0053							
2006 projection	0.0000							
G. Electrical hazards								
Lightning								0
Total hazard category citations	0	0	0	0	0	0	0	0
Frequency per 100,000 flight-hours[a]	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.000
2006 goal	0.000							
2006 projection	0.00							

[a]FAA estimated flight-hours per year:

1995	5,113,866
1996	5,976,755
1997	4,080,764
1998	4,155,670
1999	3,640,731
2000	3,922,535
2001	3,476,432

Appendix B

Acronyms and Abbreviations

ACMS	Aircraft Condition Monitoring System
ADAS	AWOS Data Acquisition System
ADDS	Aviation Digital Data Service
ADS-B	Automatic Dependent Surveillance–Broadcast
ADWSA	Automatic Delivery of Wind Shear Alerts
AFWA	Air Force Weather Agency
AHAS	Airborne Hazard Awareness System
AIP	Aircraft Icing Product
ALDA	Airborne LIDAR Detection Algorithm
AMS	Automated Meteorological System
AOC	Aviation Operations Course
AOPA	Aircraft Owners and Pilots Association
AOS	Automated Observing System
APWE	Aviation Pilot Weather Education
ARL	Air Resources Laboratory
ARNAV	ARNAV Systems, Inc.
ARS	Air Traffic Service Requirements Service (FAA)
ASAP	Advanced Satellite Aviation Products
ASF	Air Safety Foundation
ASOS	Automated Surface Observing System
ASR-9	Airport Surveillance Radar–9
ATB	Terminal Business Service (FAA)
ATC	air traffic control
ATLAS	Aircraft Total Lightning Advisory System
AUA	Office of Air Traffic Systems Development (FAA)
AvSP	Aviation Safety Program (NASA)
AWARE	Aviation Weather Awareness and Reporting Enhancement
AWC	Aviation Weather Center (NOAA)
AWH	Aviation Weather Hazards
AWHCS	Aviation Weather Hazard Characterization System
AWIN	Aviation Weather Information
AWIPS	Advanced Weather Interactive Processing System
AWOS	Automated Weather Observing System
AWRP	Aviation Weather Research Program
C&V	Ceiling and Visibility
CA	Circulation Algorithm
CAPS	Center for Analysis and Prediction of Storms (University of Oklahoma)
CCFP	Collaborative Convective Forecast Product
CDFS II	Cloud Depiction and Forecast System
CDMNET	Collaborative Decision Making Net
CIP	Current Icing Potential
CIWS	Corridor Integrated Weather System
COMET	Cooperative Program for Operational Meteorology, Education and Training
CRA	cooperative research agreement
CRREL	Cold Regions Research and Engineering Laboratory (U.S. Army)
DA	Divert Alerts
DCAFS	Dallas-Fort Worth Collaborative Aviation Forecast Study
DLAC	Distance Learning Aviation Course
DOD	Department of Defense
E&T	Education and Training Program
EAA	Experimental Aircraft Association
EDR	eddy dissipation rate
ERDC	Engineer Research and Development Command (U.S. Army)
ESE	Earth Science Enterprise (NASA)
ESID	Electrical Storm Identification Device
EWINS	Enhanced Weather Information System Training
EWxR	Enhanced Weather Radar
FAA	Federal Aviation Administration
FBWTG	FAA Bulk Weather Telecommunications Gateway
FDI	Forecasting for De-Icing
FFP	Fog Forecasting Process
FIP	Forecast Icing Potential
FIS-B	Flight Information Services–Broadcast
FISDL	Flight Information Services Data Link
FSL	Forecast Systems Laboratory (NOAA)
FY	fiscal year
GAF	Graphical Area Forecast
GIFTS	Geosynchronous Imaging Fourier Transform Spectrometer
GLDI	Global Lightning Data Integration
GOES	geostationary operational environmental satellite

GPS	global positioning system
GRC	Glenn Research Center (NASA)
GRIDS	Ground-Based Remote Icing Detection System
GTG	Graphical Turbulence Guidance
GTWAPS	Global Theater Weather Analysis and Prediction System
GWIS	Global Weather Information System
HYSPLIT	Hybrid Single Particle Lagrangian Integrated Trajectories
IFR	instrument flight rules
IHAS	Integrated Hazard Avoidance System
IMC	instrument meteorological conditions
IMETS	Integrated Meteorological System
IP	Internet Protocol
IRP	Icing Research Program (U.S. Army)
ITA	In-Situ Turbulence Algorithm
ITWS	Integrated Terminal Weather System
JAWS	Juneau Airport Wind System
LCP	Low Cloud Product
LIDAR	Light Detection and Ranging
LLWAS	Low Level Windshear Alert System
LLWAS-NE	Low Level Windshear Alert System – Network Expansion
LPATS	Lightning Position and Tracking System
MDCRS	Meteorological Data Collection and Reporting System
METAR	aviation routine weather report
METMF (R)	Marine Corps Meteorological Mobile Facility Replacement
METOC	Meteorology and Oceanography
MIAWS	Medium Intensity Airport Weather System
MIDDS-T	Meteorological Integrated Data Display System – Tactical
MIT	Massachusetts Institute of Technology
MMCR	Millimeter Cloud Radar
MMS-P	Meteorological Measuring Set – Profiler
MRC	Multi-Radar Composites
MRS	Mini Rawinsonde System
MSC	Meteorological Services of Canada
MSFS	Marine Stratus Forecast System
MWAVE	Mountain Wave
MWFM	Mountain Wave Forecast Model
NAAPS	Navy Aerosol Analysis and Prediction System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATA	National Air Transportation Association
NAW/PC	National Aviation Weather Program Council
NCAR	National Center for Atmospheric Research
NCEP	National Centers for Environmental Prediction (NOAA)
NCV	National Ceiling and Visibility
NCWF	National Convective Weather Forecast
NESDIS	National Environmental Satellite, Data, and Information Service (NOAA)
NEXRAD	Next Generation Weather Radar (WSR 88D)
NFWB	Navy Flight Weather Briefer
NITES	Naval Integrated Environmental Subsystem
NLDN	National Lightning Detection Network
NMOC	Naval Meteorology and Oceanography Command (U.S. Navy)
NOAA	National Oceanic and Atmospheric Administration
NOTAM	notice to airmen
NPOESS	National Polar-orbiting Operational Environmental Satellite System
NSDS-E	Naval Satellite Display System – Enhanced
NSF	National Science Foundation
NTDA	NEXRAD Turbulence Detection Algorithm
NTFS	New Tactical Forecast System
NTSB	National Transportation Safety Board
NWA	National Weather Association
NWS	National Weather Service (NOAA)
NWSTC	National Weather Service Training Center (NOAA)
OACD	Oceanic Automated Convective Diagnosis Product
OACN	Oceanic Automated Convective Nowcast Product
OAR	Office of Oceanic and Atmospheric Research (NOAA)
OASIS	Operational and Supportability Implementation System
OCTH	Oceanic Cloud Top Height Product
OFCM	Office of the Federal Coordinator for Meteorological Services and Supporting Research
OITFA	Oceanic Integrated Turbulence Forecast Algorithm
OPS II	Operational Weather Squadron Production System, Phase II
OPUP	Open Principal User Processor
PA	Polarization Algorithm
PCIS	PC-based Icing Simulator
PIREP	pilot report
PTI	Pilot Training Initiative
PUFF	Volcanic Ash Dispersion Model
QTP	Qualification Training Packages
R&D	research and development
RADAR	Radio Detection and Ranging
RAWS	Remote Automated Weather Sensor
RCWF	Regional Convective Weather Forecast
RUC	Rapid Update Cycle
RVR	Runway Visual Range
SBID	Satellite-Based Icing Detection
S-DARS	Satellite Digital Audio Radio Service
SIGMET	Significant Meteorological Advisory
SMOOS (R)	Shipboard Meteorological and Oceanographic Observing System Replacement

SVS	synthetic vision systems
SWAP	Severe Weather Avoidance Program
SWIS	Satellite Weather Information System
SWR	Supplemental Weather Radar
TAF	Terminal Aerodrome Forecast
TAM	Tactical Area Met program
TAMDAR	Tropospheric Airborne Meteorological Data Reporting
TCV	Terminal Ceiling and Visibility
TCWF	Terminal Convective Weather Forecast
TDWR	Terminal Doppler Weather Radar
TEDS	Tactical Environmental Data Services
TEP	Tactical Environmental Processor
TIS-B	Traffic Information Service–Broadcast
TMOS	Tactical Meteorological Observing System
TPS	Turbulence Plot System
TWR	Tactical Weather Radar
UAT	Universal Access Transceiver
UCAR	University Corporation for Atmospheric Research
VAA	Volcanic Ash Avoidance
VAFTAD	Volcanic Ash Forecast Transport and Dispersion Model
VAG	Volcanic Ash Graphic
VAP	Volcanic Ash Product
VAW	Volcanic Ash Warning
VDLM2	VHF Data Link Mode 2
VHF	very high frequency
WARP	Weather and Radar Processor
WebASD	Web-based Aircraft Situation Display
WGPP	Wind Gust Potential Product
WINCOMM	Weather Information Communications
WINN	Weather Information Network
WMSCR	Weather Message Switching Center Replacement
WRF	Weather Research and Forecasting
WSDDM	Weather Support to De-Icing Decision Making
WSP	Weather System Processor (ASR-9)
WSR 88D	Weather Surveillance Radar 1988 Doppler (NEXRAD)
WVSS	Water Vapor Sensing System
WxAP	Weather Accident Prevention Program (NASA)
WxITC	Weather-in-the-Cockpit

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