Improving Pilot Weather Report Submission and Dissemination to Benefit Safety in the National Airspace System

Special Investigation Report

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Improving Pilot Weather Report Submission and Dissemination to Benefit Safety in the National Airspace System

National Transportation Safety Board

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Abstract: The National Transportation Safety Board (NTSB) investigated several recent incidents and accidents and engaged in discussions with members of various pilot weather report (PIREP) user groups that revealed deficiencies in the handling of PIREP information that resulted in delays, errors, and data losses. These types of issues can play a role in the complex interaction of events and conditions that lead to aircraft accidents. Specifically, between March 2012 and December 2015, the NTSB investigated 16 accidents and incidents that exposed PIREP-related areas of concern. This special investigation report describes the two broad categories of issues that reduce the effectiveness of PIREPs: submission issues and dissemination issues. The NTSB makes safety recommendations to the Federal Aviation Administration, the National Weather Service, the National Air Traffic Controllers Association, the Aircraft Owners and Pilots Association Air Safety Institute, the Aviation Accreditation Board International, the National Association of Flight Instructors, the Society of Aviation and Flight Educators, and the Cargo Airline Association.

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Abbreviations

AABI	Aviation Accreditation Board International
AAWU	Alaska aviation weather unit
ABO	aircraft-based observation
AC	advisory circular
ACARS	aircraft communications addressing and reporting system
ADDS	aviation digital data service
ADS-B	automatic dependent surveillance-broadcast
AIM	*Aeronautical Information Manual*
AIREP	aircraft report
AIRMET	airmen's meteorological information advisory
AIS-R	aeronautical information system-replacement
AMDAR	aircraft meteorological data report
AOPA	Aircraft Owners and Pilots Association
ARTCC	air route traffic control center
ASRS	aviation safety reporting system
ATC	air traffic control
AWC	aviation weather center
CAA	Cargo Airline Association
CFR	*Code of Federal Regulations*
CIP	Current Icing Product
CWA	center weather advisory
CWSU	center weather service unit
EDR	eddy dissipation rate

ERAM	en route automation modernization
ERIDS	en route information display system
FAA	Federal Aviation Administration
FAASTeam	FAA Safety Team
FDIO	flight data input/output
FIP	Forecast Icing Product
FL	flight level
FSS	flight service station
GA	general aviation
GAJSC	General Aviation Joint Steering Committee
GTG	Graphical Turbulence Guidance
IFR	instrument flight rules
IMC	instrument meteorological conditions
InFO	Information for Operators
LLWS	low-level windshear
LMFS	Lockheed Martin Flight Service
MOPS	minimum operational standards
NAFI	National Association of Flight Instructors
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NATCA	National Air Traffic Controllers Association
NCAR	National Center for Atmospheric Research
NextGen	Next Generation Air Transportation System
NOAA	National Oceanic and Atmospheric Administration
NOTAM	notice to airmen

NTSB	National Transportation Safety Board
NWS	National Weather Service
NWSI	National Weather Service instruction
PED	portable electronic device
PIREP	pilot weather report
SAFE	Society of Aviation and Flight Educators
SIGMET	significant meteorological information advisory
SWIM	system wide information management
TAF	terminal aerodrome forecast
TRACON	terminal radar approach control
UA	routine PIREP
UAT	universal access transceiver
UUA	urgent PIREP
WFO	weather forecast office
WMSCR	weather message switching center replacement

Executive Summary

Pilot weather reports (PIREPs), which are brief reports from pilots describing observed in-flight weather conditions, are an important source of weather information in the National Airspace System (NAS). Complete, accurate, and timely weather information is essential to support flight safety for all aircraft operations—large and small—in the NAS; it is vital for use in avoiding inadvertent encounters with hazardous weather and preventing weather-related accidents. Historically, weather-related accidents involving general aviation aircraft that encountered poor visibility have a higher fatality rate than all other types of accidents. For US air carriers, accidents involving encounters with in-flight turbulence account for the most injuries to passengers and flight attendants. PIREPs, because they provide in situ observations, are one of the most important pieces of information that weather forecasters have when assessing the quality of their forecasts and improving graphical weather products used by pilots and others to avoid weather hazards in the NAS.

PIREP end users include other pilots, company flight-handling personnel (such as dispatchers and flight coordinators), air traffic control (ATC) personnel, National Weather Service (NWS) meteorologists, and weather researchers. For each of these user groups, the real-time information provided by PIREPs directly supports flight safety functions:

- Pilots and other company personnel use PIREPs during both strategic (longer-term) and tactical (shorter-term) route planning to avoid weather hazards.
- ATC personnel use PIREPs when making decisions about the safe and expeditious flow of air traffic in their area of jurisdiction. ATC personnel can (and, under some weather conditions, are required to) solicit PIREPs and disseminate the information.
- NWS meteorologists use PIREPs to verify or amend aviation forecast and advisory products. Weather researchers also use PIREPs to improve the accuracy of global forecast models and turbulence and icing weather products.

For PIREPs to be most effective, they must be numerous, accurate, and made available quickly in the NAS.

Why the NTSB Conducted this Special Investigation

The National Transportation Safety Board (NTSB) investigated several recent incidents and accidents and engaged in discussions with members of various PIREP user groups that revealed deficiencies in the handling of PIREP information that resulted in delays, errors, and data losses. These types of issues—because they affect the accuracy and timeliness of the weather information upon which flight safety decisions are made—can play a role in the complex interaction of events and conditions that lead to aircraft accidents. Between March 2012 and December 2015, the NTSB investigated 16 accidents and incidents that exposed PIREP-related areas of concern. The NTSB determined that PIREP-dissemination deficiencies contributed to the cause of two incidents; in both cases, the flight crews were not provided PIREPs (submitted previously by other pilots) about

hazardous weather before they encountered it. The PIREP information, if disseminated, would have increased the weather situational awareness of the incident flight crews, which could have helped them avoid the weather hazards and prevent the aircraft-damaging events. In other cases, although PIREP issues did not contribute directly to the accident and incident causes, the investigations discovered similar PIREP-related concerns. The prevalence of these issues across numerous investigations, as well as the similarities between these issues and the concerns voiced by PIREP user groups, suggests that such problems are widespread; the NTSB believes that correcting these systemic PIREP-related issues can help reduce the occurrence of hazardous weather encounters in the NAS.

What the NTSB Found

The NTSB identified several issues across user groups that reduce the effectiveness of PIREPs; these issues fall generally into two broad categories:

- **Submission issues (related to the quantity and quality of incoming reports).** Pilots are providing relatively few PIREPs, particularly during good or as-forecasted conditions, and air traffic controllers are not consistently soliciting PIREPs during weather conditions that mandate such services. Also, pilot assessments of weather conditions are subjective, and submitted reports can be inaccurate or incomplete.
- **Dissemination issues (related to the distribution of reports received).** ATC, flight service station, or company personnel who handle PIREPs can introduce delays and errors or even fail to distribute the information. Procedural inefficiencies or noncompliance, low task prioritization of PIREP processing, data-entry errors, problems with data-entry interfaces (including a lack of current automation functions for PIREPs within Next Generation Air Transportation System [NextGen] platforms), and propriety practices (in which PIREPs are not shared to the NAS) have been identified as ongoing issues.

These findings prompted the NTSB to host a 2-day forum, "PIREPs: Pay it Forward…Because Weather for One is Weather for None," on June 21-22, 2016, to facilitate a dialogue among the various PIREP user groups. Information gained from this forum and from previous NTSB investigations and meetings highlighted several opportunities for improving the PIREP system.

Recommendations

As a result of this special investigation, the NTSB makes safety recommendations to the Federal Aviation Administration, the NWS, the National Air Traffic Controllers Association, the Aircraft Owners and Pilots Association Air Safety Institute, the Aviation Accreditation Board International, the National Association of Flight Instructors, the Society of Aviation and Flight Educators, and the Cargo Airline Association. The NTSB believes that the actions recommended in this report not only will enhance safety in the near term within the constraints of the current PIREP system but also will serve as the foundation for supporting the long-term solutions associated with NextGen and other emerging technologies.

1. Introduction

Pilot weather reports (PIREPs), which are brief reports from pilots describing observed in-flight weather conditions, are an important source of weather information in the National Airspace System (NAS).[1] The PIREP format includes the aircraft type, location, and altitude; time of the report; and a description of at least one element of observed weather conditions.[2] Complete, accurate, and timely weather information is essential to support flight safety for all aircraft operations—large and small—in the NAS; it is vital for use in avoiding inadvertent encounters with hazardous weather and preventing weather-related accidents.[3] Historically, weather-related accidents involving general aviation (GA) aircraft that encountered poor visibility have a higher fatality rate than all other types of accidents (NTSB 2005). For US air carriers, accidents involving encounters with in-flight turbulence account for the most injuries to passengers and flight attendants (FAA 2015).[4] PIREPs, because they provide in situ observations, are one of the most important pieces of information that weather forecasters have when assessing the quality of their forecasts and improving graphical weather products used by pilots and others to avoid weather hazards in the NAS.

Pilots most commonly submit PIREPs verbally via radio to air traffic control (ATC), flight service station (FSS), or company personnel (like dispatchers or flight coordinators); however, pilots also have technology options to transmit the information in text format, through either aircraft equipment (common in transport-category aircraft) or web-based tools and applications for portable electronic devices (PEDs).[5] Ideally, after a pilot submits a verbal PIREP in real time, the air traffic controller, FSS specialist, or company dispatcher who receives it enters the data for electronic dissemination to the NAS, encoded in the standard format that the FAA prescribes. Or, for those PIREPs that the pilot enters directly into an application or web-based tool, the data will be encoded into the proper format and disseminated to the NAS. Depending on how the pilot submits the PIREP, its dissemination pathway to the NAS varies. (See Appendix A, Supporting Information for Section 1, "PIREP Pathways to the NAS," for more details.)

[1] For the purposes of this report, unless otherwise specified, the term PIREP refers to human-submitted data (either by voice or through manual input into a data-submission system), as opposed to data automatically collected and submitted by sensor-equipped aircraft. Although, by definition, a PIREP is a weather report, pilots can use the system to report other safety information, such as the runway condition or the presence of wildlife.

[2] Examples of reported weather conditions may include icing or turbulence (or lack thereof), cloud tops, cloud bases, visibility, precipitation, or other weather phenomena.

[3] According to one Federal Aviation Administration (FAA) study that analyzed National Transportation Safety Board (NTSB) data, weather was a cause or contributing factor in about 20% of all aviation accidents from 2003 through 2007, accounting for 1,740 accidents involving 8,754 aircraft (FAA 2010).

[4] From 1980 through 2008, US air carriers were involved in 234 turbulence-related accidents, which resulted in 298 serious injuries and 3 fatalities.

[5] (a) FSSs are operated by the FAA in Alaska and by a contract provider, Lockheed Martin Flight Service (LMFS), elsewhere in the United States. (b) Many transport-category airplanes are equipped with an aircraft communications addressing and reporting system (ACARS) that allows flight crews to send typed messages, including PIREPs, to company personnel at a ground station. Although onboard PIREP-submission capabilities are not yet widely realized in GA aircraft (currently, a few platforms use Iridium satellite-based transmission capabilities), the technology continues to evolve, and pilots' use of web-based data forms and other data-submission tools (like applications for PEDs) is increasing.

Once a PIREP has been properly disseminated and is available to the NAS, end users include other pilots, company flight-handling personnel (such as dispatchers and flight coordinators), ATC personnel, National Weather Service (NWS) meteorologists, and weather researchers.[6] For each of these user groups, the real-time information provided by PIREPs directly supports flight safety functions:

- Pilots and other company personnel use PIREPs during both strategic and tactical route planning to avoid weather hazards.
- ATC personnel use PIREPs when organizing the safe and expeditious flow of air traffic in their area of jurisdiction. ATC personnel can (and, under some weather conditions, are required to) solicit PIREPs and disseminate the information.
- NWS meteorologists use PIREPs to verify or amend aviation forecast and advisory products. Weather researchers also use PIREPs to improve the accuracy of global forecast models and turbulence and icing weather products.[7]

For PIREPs to be most effective, they must be numerous, accurate, and made available quickly in the NAS. The NTSB has investigated recent incidents and accidents and has engaged in discussions with members of various PIREP user groups and discovered deficiencies in the handling of PIREP information that have resulted in delays, errors, and data losses. These types of issues—because they affect the accuracy and timeliness of the weather information upon which flight safety decisions are made—can play a role in the complex interaction of events and conditions that lead to aircraft accidents and incidents. Between March 2012 and December 2015, the NTSB investigated 16 accidents and incidents that exposed PIREP-related areas of concern. (See Appendix B for the list of investigations.) The NTSB determined that PIREP-dissemination deficiencies contributed to the causes of two incidents; in both cases, the flight crews were not provided PIREPs (submitted previously by other pilots) about hazardous weather before they encountered it. The PIREP information, if disseminated, would have increased the weather situational awareness of the incident flight crews, which could have helped them avoid the weather hazards and prevent the aircraft-damaging events. In other cases, although PIREP issues did not contribute directly to the accident and incident causes, the investigations discovered similar PIREP-related concerns. The prevalence of these issues across numerous investigations, as well as the similarities between these issues and the concerns voiced by PIREP user groups, suggests that such problems are widespread; the NTSB believes that correcting these systemic PIREP-related issues can help reduce the occurrence of hazardous weather encounters in the NAS.

[6] Although this report focuses primarily on NAS user groups, private industry groups, government organizations, and others use PIREPs for research activities related to weather phenomena.

[7] The NWS, which maintains an extensive weather-observing program and nationwide weather forecasting service, provides a variety of weather information products, including observation reports and forecasts that are essential for flight planning. NWS aviation weather products in the United States are issued mainly from the Aviation Weather Center (AWC) in Kansas City, Missouri; the Alaska Aviation Weather Unit (AAWU) in Anchorage, Alaska; the 21 center weather service units (CWSUs) collocated with FAA air route traffic control centers (ARTCCs); and the 122 individual weather forecast offices (WFOs). Standard NWS aviation-specific forecasts and advisories include terminal aerodrome forecasts (TAFs), area forecasts, significant meteorological information advisories (SIGMETs), airmen's meteorological information advisories (AIRMETs), center weather advisories (CWAs), and meteorological impact statements.

Several issues that reduce the effectiveness of PIREPs were identified across user groups; these issues fall generally into two broad categories:

- **Submission issues (related to the quantity and quality of incoming reports).** Pilots are providing relatively few PIREPs, particularly during good or as-forecasted conditions, and air traffic controllers are not consistently soliciting PIREPs during weather conditions that mandate such services. Also, pilot assessments of weather conditions are subjective, and submitted reports can be inaccurate or incomplete.
- **Dissemination issues (related to the distribution of reports received).** ATC, FSS, or company personnel who handle PIREPs can introduce delays and errors or even fail to distribute the information. Procedural inefficiencies or noncompliance, low task prioritization of PIREP processing, data-entry errors, problems with data-entry interfaces (including a lack of current automation functions for PIREPs within Next Generation Air Transportation System [NextGen] platforms for air traffic controllers), and propriety practices (in which PIREPs are not shared to the NAS) have been identified as ongoing issues.[8]

The discovery of these issues during NTSB accident and incident investigations and PIREP user-group meetings prompted the NTSB to host a 2-day forum, "PIREPs: Pay it Forward…Because Weather for One is Weather for None," on June 21-22, 2016, to facilitate a dialogue among the various PIREP user groups to further understand the reasons for the problems and to discuss potential solutions.[9] Information gained from this forum and from the NTSB investigations and user-group meetings highlighted several opportunities for improving the PIREP system. The NTSB believes that the actions recommended in this report not only will enhance safety in the near term within the constraints of the current PIREP system but also will serve as the foundation for supporting the long-term solutions associated with NextGen and other emerging technologies.

[8] According to the FAA, NextGen is comprised of state-of-the-art technologies and procedures to improve the efficiency and safety of air traffic movement in the NAS. It involves FAA collaboration with airlines, airports, unions, and state and local governments and includes a vast foundational infrastructure of technology, equipment, and data-sharing capabilities. For more information, see the FAA's NextGen website (www.faa.gov/nextgen).

[9] To access the forum transcripts, see the docket for this Special Investigation Report (NTSB case number DCA15SR001). (The report for each event summarized in this report can be searched by case number from the NTSB's Aviation Accident Database web page, and each investigation's public docket can be accessed from the NTSB's Accident Dockets web page. NTSB documents are accessible from the NTSB's home page [www.ntsb.gov].)

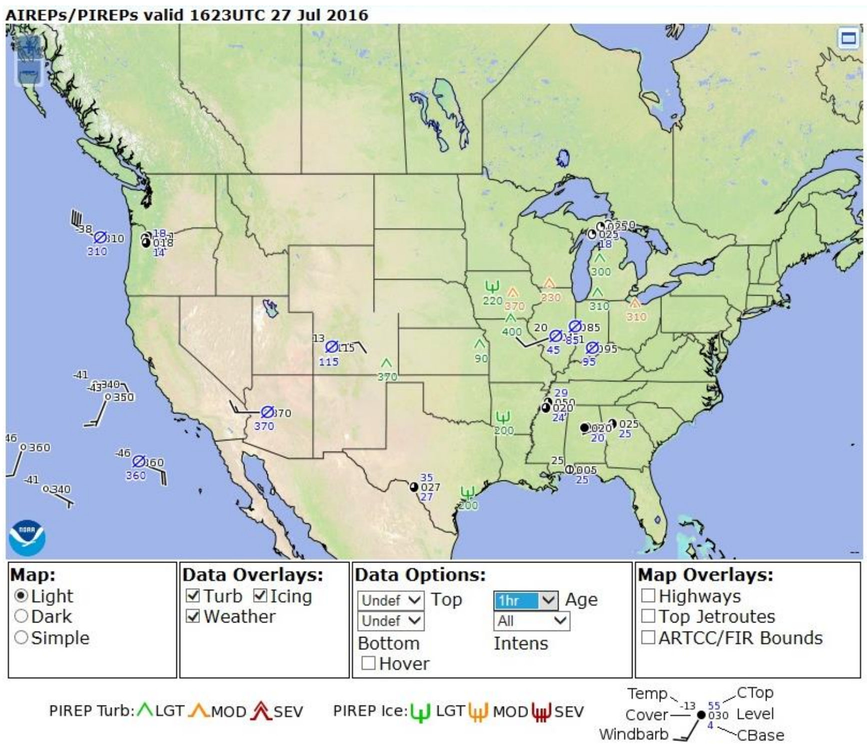
2. Need for Increased Quantity and Improved Quality of Submissions

The overall improvement in meteorology in terms of forecasting accuracy over the past 10 to 20 years can be attributed, in large part, to an increase in observational data from surface stations (NTSB 2016b, 206). However, for conditions aloft, there is no dense observation network; therefore, PIREPs are critically important. PIREPs, because they provide in situ observations, are one of the most important pieces of information weather forecasters have when assessing the quality of their forecasts and improving graphical weather products used by pilots and others in the NAS. The AWC warning coordination meteorologist who participated in the NTSB's June 2016 forum stated that PIREPs are the only way to confirm the actual conditions that are being forecasted (NTSB 2016a, 35). According to the then-acting chief of the environmental and scientific services division of the NWS Alaska region, in many instances, a single PIREP enabled a meteorologist to make a radical adjustment to a forecast, either to show conditions as much worse or much improved (NTSB 2016a, 41-42, 45).

In addition, a PIREP can be one of the most critical sources of data for a forecaster when determining whether to issue an advisory product. Forecasters have noted that even a single PIREP can influence the decision to issue (or discontinue) a hazardous weather advisory or amend its geographic area. PIREPs also provide information that improves automated products such as the Graphical Turbulence Guidance (GTG), the Current Icing Product (CIP), and the Forecast Icing Product (FIP) (FAA 2014d). Such improvements in the quality of forecasts and advisories allow for more accurate identification of areas conducive to airframe icing and turbulence and help pilots avoid such hazards. (See Appendix A, Supporting Information for Section 2, "Examples of Weather Product Uses," for more details.)

To better achieve safety improvements, it is important to increase both the quantity and quality of PIREP submissions. Although pilots value using PIREPs in their strategic and tactical flight planning, relatively few routinely provide PIREPs themselves. The Aircraft Owners and Pilots Association's (AOPA) review of results from its 2016 survey (to which about 700 primarily GA pilots responded) found that 83% of pilots who responded to the survey viewed PIREPs as either extremely or very important to aviation safety across the NAS (NTSB 2016b, 20; George 2016). However, one researcher who previously reviewed a 5-year period of PIREP data found that US pilots submitted an average of only about 90 PIREPs per hour nationwide (Casner 2010). To illustrate the significance of this rate, figure 1 graphically compares the volume of PIREPs submitted during a 1-hour period (about two dozen as shown in the top image, which is excerpted from the AWC Aviation Digital Data Services [ADDS] website) with a snapshot of the approximate volume of air traffic in the NAS captured in one instant during the same period (as shown in the bottom image, which is excerpted from the flightradar24 website).[10]

[10] The approximate volume of air traffic depicted in figure 1 is derived from certain transponder, radar, and other data.



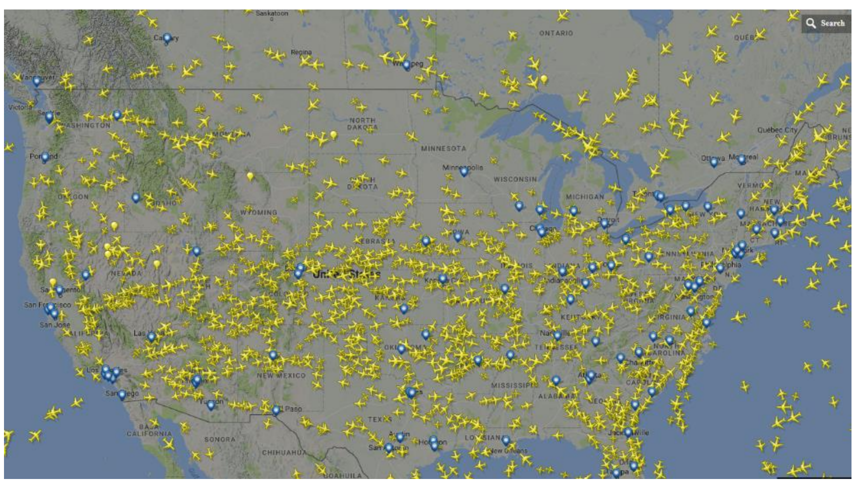


Figure 1. Comparison of PIREPs submitted during a 1-hour period in July 2016 (top) and the approximate volume of air traffic nationwide during the same period (bottom).

Sparse reporting prevents air traffic controllers and other pilots from receiving information that could help them develop enhanced situational awareness of weather scenarios. It also increases the difficulties that weather forecasters have in identifying present hazards and developing accurate forecasts and advisories, as well as adversely affecting weather model performance. According to the acting chief of the environmental and scientific services division of the NWS Alaska region, in Alaska, the large geographic area combined with very few PIREPs severely impacts forecasting ability (NTSB 2016a, 41-42, 45).

Improving the accuracy of forecasts and refining the defined geographic area and altitudes for advisories like AIRMETs is important for ensuring that pilots can trust the advisories and make appropriate decisions based on the information. For example, according to an AOPA Air Safety Institute senior air safety advisor, pilots who are repeatedly exposed to forecasts and weather advisories that predict much worse and/or more widespread conditions than they actually encounter could become conditioned to the extent that they begin to ignore the warnings (Landsberg 2016). At the NTSB's June 2016 forum, the AOPA Air Safety Institute senior air safety advisor stated that, ultimately, better forecasts will lead to better flight-planning choices, resulting in safer flights and fewer accidents (NTSB 2016a, 31).

2.1 Factors Influencing Low Number of Submissions

2.1.1 Lack of Awareness of Importance of All PIREPs

One reason that some pilots do not routinely file PIREPs may be that they are unaware of how important all PIREPs—including those of fair weather conditions or of conditions consistent with the forecast—are for improving aviation weather products. One survey of 189 GA pilots found a likely relationship between pilots' perceived importance of PIREPs and their willingness to submit them (Casner 2010). The survey results also indicated that the pilots surveyed were more likely to submit PIREPs for severe or unexpected weather phenomena than for moderate or as-forecasted conditions. The survey results strongly suggested that pilots believed that the primary purpose of PIREPs was for reporting bad weather. AOPA's review of the responses to its 2016 survey revealed a similar trend: 81% of the pilots who responded said they would rarely to never file a PIREP for as-forecast conditions, and 76% said that they would rarely to never report benign conditions (NTSB 2016b, 21).

According to the NWS AWC warning coordination meteorologist, null or good weather reports are just as valuable as any other, especially if the pilot is flying within an advisory area; for example, the flight is within the boundaries of an icing AIRMET and no icing conditions are observed (NTSB 2016a, 36). For an AIRMET area, PIREPs of negative turbulence or icing could provide meteorologists with the information that they need to condense the AIRMET to a much smaller area (NTSB 2016a, 173). Further, from an ATC perspective, negative PIREPs have enabled controllers to route aircraft through blocks of altitude that they had previously routed traffic around (NTSB 2016a, 176). A National Center for Atmospheric Research (NCAR) associate scientist noted that PIREPs from both sides of weather transition zones (for example, if flying from icing conditions to no icing, rough air to smooth, or clouds to no clouds) are helpful for weather product development (NTSB 2016a, 62-63).

A review of the PIREP guidance in the *Aeronautical Information Manual* (AIM), as well as private pilot and other aviation educational materials published by some popular aviation education vendors, found that these resources and some other publications provide relatively little information about the benefits of PIREPs beyond tactical uses and do not emphasize the importance of all reports for improving the accuracy of weather forecast products. For example, although AIM section 7-1-19, "PIREPs," states in paragraph (b) that pilots are encouraged to cooperate and promptly volunteer reports of certain atmospheric data, the remainder of AIM guidance for PIREPs focuses primarily on how to report icing, turbulence, visibility restrictions, and other hazards; it provides no information about the relevance of fair-weather PIREPs.

Recent FAA and industry efforts have sought to improve pilot awareness of the importance and uses of PIREPs. In May 2014, the FAA and GA groups launched a collaborative, 8-month, national safety campaign (titled, “Got Weather?”) that included PIREP awareness.[11] The FAA’s “Got Weather?” web page contains links to weather educational materials, including some archived PIREP-related resources, such as an FAA article from 2008 that explains the importance of all PIREPs and encourages pilots to submit at least one PIREP on every flight. Also, in October 2014, the NWS/FAA Advisory Circular (AC) 00-45G, Change 2, “Aviation Weather Services,” was revised to include language emphasizing that the accuracy of the analysis in some weather forecast products is dependent on the number of PIREPs available (FAA 2014a).[12] The revised AC explains the relevance of both fair-weather and poor-weather reports for improving the accuracy of NWS forecasts and products and encourages pilots to “Pipe Up with a PIREP and help the aviation community operate more safely and effectively.”

Also in 2014, the Alaska Flight Services (representing FSSs in Alaska) PIREP Improvement Initiative and the efforts of its associated working group were launched. This campaign, which sought to improve the quality, quantity, and effectiveness of PIREP solicitation and dissemination in Alaska, included educational outreach to both ATC and pilot groups (FAA 2014b). According to an FAA FSS specialist, the improvement initiative included measuring the number of PIREPs processed and auditing them for accuracy; conducting a survey of local pilots to learn more about how they submit (or why they do not submit) and use PIREPs; and developing training, best practices, and checklists for FSS specialists (NTSB 2016a, 133-134). In December 2016, AOPA reported that Alaska Flight Services handled more than 3,000 PIREPs in July 2016, which represented a 39% increase in PIREPs compared to July 2015 with only a 1.3% increase in air traffic (as determined by the number of radio contacts Alaska Flight Services personnel had with pilots for the month); August and September 2016 also showed increased PIREP numbers over the previous year (George 2016). Although the separate effects of the pilot education and other outreach components and the possible effects of weather variables are not known, the initial campaign results suggest that a multifaceted approach of targeted outreach that engages multiple PIREP user groups may be a successful way to increase the number of PIREPs submitted.

More recently, in February 2016, Alaska Flight Services released a 3-minute video (which was aired statewide on network television and posted on YouTube) to educate pilots about the importance of PIREPs for improving weather forecasts and situational awareness. In the video, the Alaska Flight Services staff manager expressed his concern about a recent decrease in reports. The

[11] According to the FAA’s “Got Weather?” web page (www.faa.gov/about/initiatives/got_weather/), campaign partners with the FAA are AOPA, Aircraft Electronics Association, Experimental Aircraft Association, FAA Safety Team (FAASTeam), General Aviation Joint Steering Committee (GAJSC), General Aviation Manufacturers Association, Helicopter Association International, National Agricultural Aviation Association, National Air Transportation Association, National Association of State Aviation Officials, National Association of Flight Instructors (NAFI), National Business Aircraft Association, National Oceanic and Atmospheric Administration (NOAA), NWS, Soaring Society of America, Society of Aviation and Flight Educators (SAFE), University Aviation Association, and United States Parachute Association.

[12] The AC was subsequently revised in November 2016 to AC 00-45H (FAA 2016a).

video explained to pilots the need for PIREPs on adverse and clear weather and braking action reports and how valuable PIREPs are to all users in the NAS. It included such examples as a pilot trying to make a good "go/no-go" decision and commercial airline passengers who fasten their seatbelts in response to a prompt from the captain who received a report of turbulence (FAA 2016c). The video also showed Alaska Flight Services personnel at their stations and included audio of a pilot providing a fair-weather PIREP. All of these attributes of the video are consistent with scenario-based training, which uses real-world examples to illustrate challenges and benefits in relatable circumstances to foster a deeper understanding of and connection to the information being taught.

2.1.2 Lack of Confidence in PIREP Format or Weather Assessment Skills

Another reason for a lack of reporting may be that some pilots are not comfortable with the PIREP format or are not confident in their ability to assess weather accurately. Findings from the research survey of 189 GA pilots suggest that improved weather recognition skills and improved familiarity with the PIREP format would likely lead to an increase in the volume of reported weather (Casner 2010). However, during the NTSB's June 2016 forum, an AOPA regional manager noted that his preliminary review of AOPA's recent survey results found that about 71% of the 700 pilots who responded indicated that their initial training had placed little to no emphasis on PIREPs (NTSB 2016b, 20). Pilots who may not have practiced assessing weather and filing PIREPs during initial training or who do not routinely submit them in the operational environment may find the process intimidating.

Guidance in the AIM attempts to ease such concerns by emphasizing that, although pilots should try to be as complete and concise as possible when giving a PIREP, relaying the information is more important than adhering to the strict format. The guidance reassures pilots that the person who receives the PIREP will request clarification if it is needed (FAA 2016b). Also, AC 00-45H contains more extensive information than the AIM on how to report and read PIREPs, how to apply intensity modifiers for precipitation and other weather phenomena, and how to use the remarks section to further describe the weather phenomena. These resources, which provide the foundation for helping pilots develop knowledge of the terms and modifiers used for describing observed weather in PIREPs, are discussed further in section 2.2.2. Additional education may also help pilots develop confidence and skill in assessing weather and reporting PIREP elements as described in the AIM and the AC. As discussed in the previous section, scenario-based content that uses real-world examples can foster a deeper understanding of the concepts, and online courses can be an effective way to deliver scenario-based content. One study that addressed weather-related topics for GA pilots found that a 2-hour training program was effective for fostering weather-related knowledge and skills (Blickensderfer et al. 2015).[13]

[13] In this study, the training course was lecture based and delivered by an instructor who was not involved in creating the module. The study noted that a viable training program for widespread use should be designed to be delivered successfully by more than one instructor.

The FAASTeam offers online educational modules to promote pilot learning in several safety topics and awards pilots WINGS program credits for successfully completing the courses.[14] Among the course offerings is the AOPA Air Safety Institute's online "SkySpotter: PIREPs Made Easy" interactive education course, which explains the importance of PIREPs and provides guidance on how to submit them.[15] The course contains a printable checklist that pilots can keep in the cockpit to help organize their reports and includes visual references to help pilots learn to assess cloud cover elements and interactive elements to help pilots learn to classify other weather phenomena, like turbulence. These tools can be helpful to pilots for improving their knowledge. However, the course, which was introduced in 2007, now contains some outdated references and inactive web page links. Also, although the course mentions that PIREPs are important and contains references to the AIM, it does not refer to the more detailed PIREP-reporting guidance in AC 00-45H or provide real-world examples of how weather forecasters use PIREPs to improve and revise aviation weather forecast and advisory products. It also does not provide real-world examples to show pilots how a PIREP submitted by one pilot can directly enhance safety for other pilots.

As previously noted, scenario-based examples can have a powerful impact on learning. For example, during the NTSB's June 2016 forum, one educator described a scenario-based lesson that she taught to her students about a particular weather-related accident involving a commercial airline flight that crashed during approach to land, resulting in 134 fatalities. In the scenario, she described for the students how a pilot in a Learjet landed his airplane just a few minutes before the accident flight but did not report the wind conditions that he encountered.[16] After the Learjet pilot successfully landed his airplane and began to taxi, he looked back toward the approach end of the runway and saw smoke coming up from the crash site of the airplane that had been behind him on the approach. The educator stated that she believed that this scenario-based example made an impression on the students that "keeping the weather [information] to ourselves is not the best thing that we can do" (NTSB 2016b, 72-73).

As mentioned previously, scenario-based pilot education was one component of the Alaska Flight Services PIREP Improvement Initiative, which may have resulted in the measured increase in PIREPs in that region. Thus, the NTSB concludes that education that fosters pilot understanding of the importance and uses of all PIREPs, weather-assessment and -reporting skills, and familiarity with the PIREP format can increase the likelihood that pilots will file PIREPs. Also, because more than half of all PIREPs are submitted by GA pilots (Casner 2010) and because the same skills apply to airline transport pilots (who transitioned through private pilot training and may also be active in the GA community), the NTSB believes that the GA pilot population is the appropriate audience for such education. In addition, due to its leadership role in conducting its 2016 PIREP

[14] The FAASTeam provides access to online training courses, seminars, and webinars as part of the FAA's "WINGS—Pilot Proficiency Program," which includes targeted flight training designed to help pilots develop the knowledge and skills needed to achieve flight proficiency and to assess and mitigate the risks associated with the most common causes of accidents.

[15] The AOPA Air Safety Institute's "SkySpotter: PIREPs Made Easy" course can be accessed from the FAASTeam website (www.faasafety.gov). (Course access requires login through a free FAASTeam account.)

[16] The example the educator provided was the August 2, 1985, accident in Fort Worth, Texas (NTSB case number DCA85AA031) in which a Lockheed L-1011-385-1 encountered microburst-induced severe windshear during approach to land (NTSB 1986). In its report (the format of which differs from contemporary reports), the NTSB listed "Flight advisories…Not issued…Pilot of other aircraft" as a contributing factor to the accident.

survey, analyzing the data, and conducting follow-up activities to assess the potential for the effectiveness of the PIREP improvement initiative in Alaska, the NTSB believes that the AOPA Air Safety Institute is well equipped to provide such PIREP education. Therefore, the NTSB recommends that the AOPA Air Safety Institute update its online PIREP course content to include, at a minimum, scenario-based training that uses real-world examples that (1) illustrate the value of both fair-weather and adverse-weather PIREPs, (2) explain how meteorologists use PIREPs to verify and revise aviation weather forecasts and advisory products to improve safety in the NAS, (3) provide guidance on how to assess and describe weather phenomena and report their location accurately, and (4) demonstrate the various ways to submit PIREPs.

In addition to education, increasing pilots' confidence and skill with assessing weather and filing a PIREP can be further accomplished through training in the operational environment. Pilots can practice filing PIREPs during primary flight training (for student pilots) and during flight reviews (for certificated pilots). Certificated flight instructors who work with pilots in the operational environment can help them gain proficiency in assessing weather phenomena and accurately reporting the location (accuracy in weather assessment and location reporting are discussed in section 2.2).

Also, because each method of filing PIREPs has strengths and weaknesses depending on the flight circumstances, practice with each method could help pilots decide which methods to choose. For example, if a pilot believes that a PIREP may provide immediate tactical information to other pilots in the area (such as a report of icing or turbulence), filing the report with an air traffic controller would likely result in the most rapid local dissemination of the information. Another option would be to file the report with an FSS specialist, which would likely result in the most direct dissemination to the NAS; however, filing a report with an FSS requires switching to a different radio frequency. Or, a pilot may note the location, time, and conditions in flight and then file the PIREP after landing with either an FSS or through a web-based tool or application, but this would result in an obvious delay. Training could help a pilot learn how to compare all of these options and make the best choices, depending on the content of the PIREP and other factors, like cockpit workload (discussed in the next section).

According to an educator who participated in the NTSB's June 2016 forum, flight instructors from her university and other local flight schools told her that they did not emphasize PIREPs with students during primary flight instruction because the focus was on maneuvering (NTSB 2016b, 31). Another educator who participated in the forum (and who is on the Board of Trustees of the Aviation Accreditation Board International [AABI]), noted that the new airman certification standards for private pilots, which became effective June 15, 2016, referenced PIREPs as a specific knowledge item.[17] He said that, because PIREPs are part of the test standards, pilots will be taught about them, but PIREPs are likely not a focal point of the training. He suggested that PIREPs could be incorporated into overall discussions with students of situational awareness and risk management tools. He also noted that pilots may benefit from learning how other stakeholders, such as air traffic controllers, use PIREP information. Both educators believed that

[17] According to AABI's website (www.aabi.aero/), the organization's mission is to advance aviation education worldwide through accreditation and leadership. Its members include dozens of universities, as well as training centers, airlines, and other groups involved in pilot training and education.

PIREP submissions would increase if flight schools incorporated the practice into their standard operating procedures (NTSB 2016b, 37-41, 58, 66, 70).

Flight instructors play a critical role in shaping the safety habits of the pilots they teach. According to the SAFE executive director, flight instructors who teach new pilots have the greatest influence in this area (NTSB 2012, 134).[18] According to the NAFI executive director, flight instructors who provide pilots with recurrent training and flight reviews also play a vital role in demonstrating best practices and helping pilots develop skills, proficiency, and habits that will make them safer pilots (NTSB 2012, 138-139).[19] Thus, the NTSB concludes that pilots who learn how to file PIREPs during initial flight training and who practice the skill during recurrent training and flight reviews are more likely to routinely submit PIREPs. Therefore, the NTSB recommends that AABI, NAFI, and SAFE encourage their members to teach their students, during initial flight training, recurrent flight training, and flight reviews, the importance of PIREPs and include, at a minimum, (1) real-world examples that illustrate the value of both fair-weather and adverse-weather PIREPs; (2) explanations of how PIREPs are used by and benefit various users in the NAS; (3) examples of the various ways to submit PIREPs while minimizing distraction; and (4) practical experience assessing weather and submitting a PIREP of the observed phenomena, including reporting their location accurately.

2.1.3 Cockpit Workload

As previously mentioned, the mechanism by which a pilot can submit a PIREP varies. Cockpit workload can be a prohibitive obstacle, both for PIREPs submitted verbally or those entered into ACARS or another application. Pilots who are flying in instrument meteorological conditions (IMC), transiting a high-traffic area, or handling other workload-intensive flying tasks may find it difficult to file a PIREP. In addition, pilots may be reluctant to interrupt communications on an already congested ATC frequency or to briefly leave an ATC frequency to file a PIREP with an FSS specialist for fear of missing important ATC instructions or advisories.

During the NTSB's June 2016 forum, an AOPA regional manager reported that a preliminary review of the responses from about 700 pilots who responded to AOPA's recent PIREP survey revealed a theme among the comments: several pilots reported that the process of leaving an ATC frequency, finding the correct FSS frequency, and then communicating with FSS was too time consuming.[20] Pilots described filing PIREPs with FSSs as inefficient because they are "held on to play 20 questions" or verify read-backs of the information (NTSB 2016b, 20-23). Other pilots provided similar comments to the NTSB's PIREPs forum e-mail address.

[18] According to its website (www.safepilots.org/), SAFE is dedicated to "fostering professionalism and excellence in aviation through continuing education, professional standards, and accreditation."

[19] According to its website (www.nafinet.org), NAFI is dedicated to "raising and maintaining the professional standing of the flight instructor in the aviation community." Part of its purpose is to "serve as a central point for the dissemination of knowledge, methodology, and new information relative to flight training."

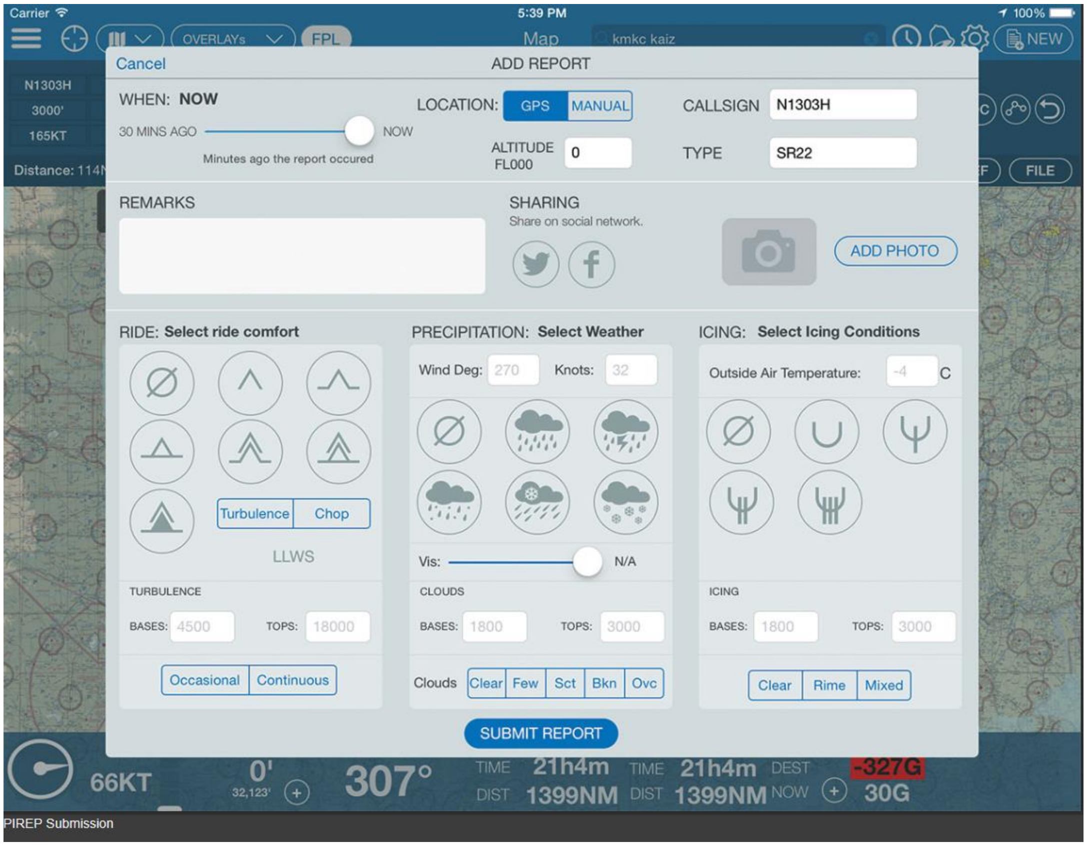
[20] The FAA decommissioned the dedicated en route flight advisory frequency of 122.0 MHz, also known as "Flight Watch," on October 1, 2015. Flight Watch was staffed by FSS personnel to provide en route aircraft with weather information and to collect and disseminate PIREPs. The FAA reported on its Flight Service web page (www.faa.gov/about/office_org/headquarters_offices/ato/service_units/systemops/fs/changes/) that the change was made to eliminate redundant services to improve system efficiency and reduce costs.

According to the AOPA regional manager, AOPA representatives recently met with LMFS and FAA personnel who confirmed that, to meet the FAA-defined quality standards, LMFS procedures require specialists to read back PIREPs to pilots and receive an acknowledgement from the pilot that the read-back information was correct (NTSB 2016b, 178). Some pilots may not realize that, unlike an air traffic controller (who already has some information about the aircraft type, altitude, and location if the pilot of a transponder-equipped aircraft has been in communication), an FSS specialist has no such information upon initial contact with the pilot (and, thus, will have to ask for it). The LMFS chief architect stated that most of the specialists' workload in recent years has shifted toward automation and the advanced weather and alerting services it enables (discussed further in section 5); however, he acknowledged that modernization away from the manual PIREP method cannot happen overnight and that improvements for FSS specialists and for controllers are relevant (NTSB 2016a, 122-123).

Documenting thorough and accurate PIREP information is important; however, some flight circumstances place demands on the pilot such that he or she must minimize the time spent filing a report. Pilots can reduce time spent filing a report by concisely providing thorough and accurate information, and specialists can help by prioritizing how critical information is obtained from the pilot. The NTSB concludes that the process by which FSS specialists receive and verify verbal PIREP information is having an unintended deterrent effect on reporting because some pilots find the process too time consuming and, therefore, choose not to submit PIREPs. Therefore, the NTSB recommends that the FAA review the process by which federal and contract FSS specialists receive verbal PIREPs and then simplify procedures to reduce the amount of time the specialists take to obtain the necessary information from pilots.

Comments that pilots provided to AOPA in its 2016 survey about workload challenges are consistent with results of an earlier research survey, which found that, of 189 GA pilots who responded, 58% reported that they were interested in a quicker, easier way to submit a PIREP (Casner 2010). Another survey conducted in 2014 found that GA pilots estimated that they would be more likely to submit PIREPs if they had an improved cockpit interface, such as a display that captured in a single button-push parameters such as aircraft location, time, altitude, aircraft type, wind, and temperature, and provided menus for selecting the other elements of a PIREP (Casner 2014).

The technology to accomplish some of these tasks is already available. Reporting features are under continuous development by avionics manufacturers, other equipment manufacturers, and developers of applications for PEDs like tablets and smartphones. These include PIREP-submission tools that allow pilots to input and transmit PIREP data directly to LMFS for dissemination through the weather message switching center replacement (WMSCR) to the NAS. Such tools are available in some popular flight-planning applications, such as Aerovie's free PIREP tool for use with the iPhone or iPad (see figure 2). Tools like the Aerovie application automatically populate the PIREP form with user-defined preset values (such as aircraft type) and, when GPS enabled, can automatically populate the PIREP form with the time, aircraft location, and flight level (FL) when a PIREP is created. If cockpit workload is too great for the pilot to complete the PIREP during the flight, the application allows the pilot to manually adjust this information to file the report after landing (NTSB 2016b, 148-149).



Source: www.aerovie.com

Figure 2. Screenshot of a PIREP-submission tool on a smartphone application.

Although electronic-submission tools may help simplify some PIREP tasks, the tools require some head-down time and are subject to connectivity limitations, and their use is not currently widespread. (See Appendix A, Supporting Information for Section 2, "Current Limitations of Electronic Submission Tools," for more details.)

2.1.4 Fear of Enforcement Action

Another issue that may deter voluntary PIREP submission is pilots' fear of enforcement action against their certificates if they file a PIREP for an inadvertent encounter with adverse conditions for which either the pilot is not rated to fly (such as an encounter with IMC without having an instrument rating) or the aircraft is not certificated to operate (such as an encounter with airframe icing in an aircraft that is not equipped for such operations). The enforcement concern, therefore, is expressed primarily by pilots of GA airplanes.

AOPA's review of its 2016 survey data found that about 16% of the pilots who responded (107 out of 675) expressed a concern about enforcement. Given that weather-related accidents have the highest fatality rate in GA, it is unfortunate that pilots might withhold critical safety information based on enforcement fears; the consequences of even one unreported icing or low-visibility encounter in a mountain pass could be deadly. For example, one pilot in a Cessna 180 filed a PIREP that reported that the flight was unable to remain in visual meteorological conditions over the mountains along the specified route and that the pilot was returning to the departure airport.[21] This information was potentially life saving to other pilots and helpful to weather forecasters, particularly if the conditions were unexpected. Because of the importance of such hazardous-weather PIREPs, the NTSB believes that enforcement fears that could deter such reports needs to be addressed.

One mechanism that may ease pilots' fears of enforcement is the availability of the aviation safety reporting system (ASRS), which is administered by the National Aeronautics and Space Administration (NASA) and is described in AC 00-46E, "Aviation Safety Reporting Program," and 14 *Code of Federal Regulations* (*CFR*) 91.25. The purpose of the program is to maintain and improve safety in the NAS by providing a means by which pilots (and other NAS users) can submit a report of an aviation safety incident so that others in the NAS can benefit from the information. The ASRS collects, analyzes, and responds to these reports to identify deficiencies in the NAS so that the appropriate authorities can address them, and the program data are used to support human factors safety research. Although a pilot may be subject to an FAA enforcement action, by reporting a safety concern to the ASRS, a pilot may potentially avoid suspension or revocation of his or her pilot certificate for a reported event that may be in violation of regulations, provided that the action was "inadvertent and not deliberate" and did not involve a criminal offense (and the person involved in the violation meets other criteria, as specified in AC 00-46E).

During the NTSB's June 2016 forum, the ASRS program director discussed the qualifications for protection provided by the ASRS and noted that there are some exceptions. An AOPA Air Safety Institute senior safety advisor mentioned that some scenarios may be open to interpretation, particularly regarding what may be considered flight into known icing conditions (NTSB 2016a, 168-170). These discussions illustrate the need for FAA clarification on these issues. Thus, the NTSB concludes that educating pilots about the safety benefits of hazardous-weather PIREPs, FAA enforcement policies related to PIREPs, and the potential protections of the NASA-administered ASRS may encourage more pilots to file a PIREP in the event of an inadvertent encounter with hazardous weather. One means by which the FAA has explained safety topics to pilots is through its *FAA Safety Briefing* magazine. Past articles have remained readily searchable and accessible for years. Therefore, the NTSB recommends that the FAA develop and distribute information that emphasizes the safety importance of hazardous-weather PIREPs and explains examples of regulatory violations in which the FAA may use PIREPs in enforcement action, as well as the potential protection from sanction under the ASRS.

2.1.5 Past Experience with Reports Not Disseminated

Another issue that may discourage voluntary PIREP submission is pilots' perception that the information is not being disseminated to the NAS. One AAWU meteorologist reported that, while he was conducting PIREP educational outreach to a pilot group, a pilot told him that he did not believe that submitted PIREP information was being widely disseminated, and the pilot confirmed his belief by noticing that his own PIREP for icing never appeared in the system. Similar anecdotes were provided by several panelists at the NTSB's June 2016 forum and by pilots who

[21] The actual PIREP was "ENA UA /OV ENA-JLA /TM 0400 /FLUNKN /TP C180 /RM ATTEMPTED VFR ENA DCT CDV, UNABLE VFR OVR MTNS, RTNG ENA AWX=."

submitted comments using the forum's e-mail address (NTSB 2016a, 37, 82; NTSB 2016b, 23, 102). Dissemination issues (and solutions) are discussed further in section 3.

2.2 Factors Adversely Affecting Accuracy

2.2.1 Position and Time Reporting Errors

The PIREP format includes the time that the weather phenomena were observed, and location is reported as distance and direction from the nearest airport or navigational aid. Depending on cockpit workload and other factors, noting the time and location may be difficult for pilots. For example, during the investigation of a serious-injury accident involving a Bombardier CL-600 airplane that encountered turbulence in McCook, Nebraska, in June 2015, the NTSB found that the actual location, altitude, and time of the turbulence encounter (derived from flight data recorder information) differed greatly from what was documented in both an initial PIREP and a corrected PIREP that were disseminated to the NAS.[22] The captain notified both company dispatch (via ACARS) and ATC of the event location, but, due to the immediate need to first fly the aircraft, request course deviations, and assess the status of the passenger injuries, he could not recall the exact timing of when he made the notifications. The inaccurate PIREP, which differed from the actual weather encounter by more than 140 miles, 1,000 ft of altitude, and about 20 minutes, had no value in potentially helping other pilots tactically avoid the area of turbulence or for helping meteorologists verify their forecasts or issue advisories.

Although this example represents unusual circumstances (in terms of the cockpit workload and distractions during an emergency), PIREP location errors of several miles are common. For example, one study that compared human-submitted turbulence PIREPs with automated data captured by aircraft sensors found that, on average, the human-submitted PIREPs contained distance errors that range from about 22 to 28 miles (Pearson and Sharman 2013). Weather researchers rely on accurate time, location, and FL information to avoid introducing errors that directly affect the weather products that NAS users rely on daily (NTSB 2016a, 59). Although onboard technology (avionics or applications like those described in section 2.1.3) can help capture time, location, and altitude information, pilots must be diligent in accurately noting and reporting these for observed weather phenomena.

2.2.2 Lack of Consistent Guidance and Criteria in FAA Publications for Reporting Some Weather Phenomena

FAA publications are a primary source of PIREP information taught to pilots in the classroom (NTSB 2016b, 173). AIM paragraphs 7-1-19 through -24 are widely referenced in PIREP educational materials (including the previously referenced online PIREP course) for pilots, air traffic controllers, and FSS personnel; AC 00-45H, "Aviation Weather Services," is also commonly referenced. Both documents define icing types, rates of ice accumulation, turbulence intensity criteria, windshear reporting guidance, and other information to help pilots and other users determine the correct modifiers for categorizing and classifying the intensity of observed weather phenomena. However, for some weather phenomena, neither publication provides

[22] For more information, see the Weather Study for NTSB case number DCA15CA131.

guidance or defines criteria for reporting certain information that meteorologists need, and, in some cases, the two publications provide conflicting information. Sections 2.2.2.1 and 2.2.2.2 discuss examples for which guidance and reporting criteria do not exist or are inconsistent, which can lead to the omission of relevant information in PIREPs and reports that are based on pilots' subjective interpretations of observed phenomena.

2.2.2.1 Turbulence and Low-Level Windshear

The guidance in the AIM and AC 00-45H differs about whether cloud information should be included in a turbulence PIREP: the AIM states that a turbulence report should specify whether the aircraft was "in or near clouds," and AC 00-45H states that it should specify "when reported, whether in clouds or clear air." Similarly, for low-level windshear (LLWS) reports, the AIM states that pilots should "report the loss or gain of airspeed" and includes examples such as "loss of 20 knots at 400 feet" or "gained 25 knots between 600 and 400 feet followed by a loss of 40 knots between 400 feet and the surface." However, AC 00-45H states only that "LLWS is described to the extent possible" and provides as an example, "airspeed fluctuations of plus or minus 15 knots, surface to 800 feet during climb."

These types of inconsistencies have real-world consequences. For example, AWC forecasters have noted that, when reporting turbulence, pilots often do not specify whether the aircraft was in clouds or out of clouds at the time of the encounter. Forecasters have also noted that pilots tend to omit specifying in LLWS reports whether an airspeed gain or loss occurred (pilots instead describe the effect on airspeed with the phrase "plus or minus" without specifying which applies). These types of omissions make it more difficult for meteorologists to validate LLWS forecasts, particularly at airports for which a PIREP is the only source of LLWS information (NTSB 2016a, 78).

In addition, the PIREP section of the AIM does not include coding charts for the text element identifiers of a report, nor does it refer to AC 00-45H, where such PIREP-coding guidance can be found. Although the AIM includes some coding elements in example PIREPs, more comprehensive coding guidance (like that found in AC 00-45H) is relevant to reducing errors and omissions, particularly as more options for pilots to electronically submit textual PIREPs (some of which may require the pilot to encode the report elements) become available. Finally, as discussed in section 2.1.1, unlike AC 00-45H, the AIM does not provide specific guidance about providing fair-weather PIREPs or the relevance of such reports for improving the accuracy of weather forecast products; however, AC 00-45H does provide such information.

The NTSB concludes that a single source of standardized guidance for PIREP reporting and coding, as well as weather assessment and classification criteria for LLWS, turbulence, and fair weather, can help reduce omissions and subjectivity errors in PIREPs. Therefore, the NTSB recommends that the FAA, in collaboration with the NWS, (1) revise and harmonize the PIREP guidance in the AIM and AC 00-45H, including but not limited to the guidance and criteria for reporting LLWS (to specify airspeed gain or loss), turbulence (to specify in-cloud or out-of-cloud), and fair weather; and (2) revise the AIM to either include comprehensive PIREP-coding guidance or to clearly reference AC 00-45H as the source of this information. The NTSB further recommends that the NWS work with the FAA to (1) revise and harmonize the PIREP guidance in the AIM and AC 00-45H, including but not limited to the guidance and criteria for reporting

LLWS (to specify airspeed gain or loss), turbulence (to specify in-cloud or out-of-cloud), and fair weather; and (2) revise the AIM to either include comprehensive PIREP-coding guidance or to clearly reference AC 00-45H as the source of this information.

2.2.2.2 Mountain Wave Activity

Mountain wave activity, which can induce large airspeed and altitude excursions that pose a serious flight safety hazard, has no defined PIREP text element identifier and, as such, has no standard guidance for reporting it or for classifying its unique characteristics.[23] Mountain waves are frequently classified as turbulence in PIREPs with more detailed information provided as free text in the remarks section of the report.[24] However, some mountain wave encounters are smooth and do not involve an associated reaction inside the aircraft that meets the AIM-defined criteria for classifying turbulence (NTSB 2016a, 72). This could result in a report of turbulence without an associated intensity classification when pilots or others attempt to code the undefined phenomenon.

In addition, the contents of the PIREP remarks field, although useful to improve situational awareness for pilots and air traffic controllers, cannot be used by weather programs to automatically create graphical depictions of PIREPs; the remarks also cannot be used in weather research for algorithm development and statistical calculations. The lack of reporting criteria for mountain wave activity and the inability to optimally display the data can result in misidentification of the weather phenomenon or inconsistencies in how related PIREPs are coded; this creates problems for pilots or ground personnel who attempt to encode reports as routine or urgent, meteorologists who must determine whether the reported conditions should trigger an advisory, and all NAS users of graphical depictions of PIREPs.[25]

For example, a PIREP filed by the pilot of an Airbus A380-800 transport-category airplane reported a mountain wave encounter that resulted in altitude fluctuations of +/-1,000 ft and airspeed changes of +/-10 knots. The PIREP type was coded as urgent, the phenomenon was coded as "turbulence," and the altitude and airspeed information was reported in the remarks section of the report.[26] Even though the PIREP identified the encounter as "turbulence," it did not include

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[23] Because of the significance of mountain wave activity as a unique aviation weather hazard, on May 6, 2014, the NTSB issued Safety Recommendations A-14-14 to the FAA and A-14-18 to the NWS that recommended that each agency provide a primary aviation weather product that specifically addresses both the potential for and the existence of mountain wave activity and the associated aviation weather hazards. Safety Recommendation A-14-14 was classified "Open—Acceptable Response" on February 9, 2016, and Safety Recommendation A-14-18 was classified "Open—Acceptable Response" on September 26, 2014. (The full text of safety recommendations and the history of correspondence can be accessed from the NTSB's Safety Recommendations web page.)

[24] Per the AIM, the remarks section can be used for reporting phenomena for which there are no text element identifiers or for clarifying reported items.

[25] PIREPs can be coded as routine (UA) or urgent (UUA). An urgent PIREP describes weather phenomena that represent a hazard or potential hazard to flight operations. Guidance for air traffic controllers (FAA Order JO 7110.10Y, "Pilot Weather Report," section 9-2-10, "PIREP Classification") states that reports of severe icing, LLWS with speed fluctuations of 10 knots or more (or speed fluctuations not reported), tornadoes, hail, and other hazardous or potentially hazardous weather phenomena meet the criteria to categorize the report as an urgent PIREP. Guidance for pilots in the AIM does not specify what conditions meet the criteria for an urgent PIREP.

[26] The actual PIREP was "COD UUA /OV COD310040/TM 0030/FL400/TP A388/TB MTN WAVE +/-1000FT +/-10KTS/RM ZLC."

any intensity classification (it is possible that it was a smooth wave encounter, and, in the absence of intensity classification criteria, the information was left blank). As a result, the AWC ADDS depiction of this urgent PIREP on a graphical information product appeared as the text “UUA mtn wv” without an associated symbol or color code.[27]

In another example, a pilot of a Boeing 757 filed a PIREP for a mountain wave encounter that resulted in airspeed changes from +20 to -40 knots. The PIREP, which was classified as routine, used the PIREP element “turbulence” with the intensity classification of “light”: the remaining information about the event was included in the remarks area of the PIREP.[28] The graphical depiction for this report, which involved large and potentially hazardous effects on airspeed, would appear simply as a routine light turbulence report.

Without defined criteria for reporting mountain wave activity, each of these hazardous weather encounters were encoded differently, and the graphical depictions of each event did not clearly reflect the unique characteristics of the weather phenomena or the intensity of the hazard. The NTSB concludes that defining the criteria for reporting the unique characteristics of mountain waves and for classifying their intensity in PIREPs and educating pilots on these criteria and classifications will increase the usefulness of the PIREPs for a variety of safety functions in the NAS, including tactical hazardous weather avoidance and the development of forecasts and weather advisory products.

Therefore, the NTSB recommends that the FAA, in collaboration with the NWS, revise the AIM and AC 00-45H to define standard criteria for reporting mountain wave activity in PIREPs that include (1) consideration that not all hazardous mountain wave encounters involve turbulence; (2) airspeed fluctuation range, altitude fluctuation range, and any other information needed to adequately describe the effects of the mountain wave activity on the aircraft; (3) parameters for classifying the intensity level of the conditions for a turbulent wave encounter and a smooth wave encounter; and (4) the threshold at which the PIREP for each type of encounter (turbulent or smooth) should be coded as urgent. The NTSB further recommends that the NWS work with the FAA to revise the AIM and AC 00-45H to define standard criteria for reporting mountain wave activity in PIREPs that include (1) consideration that not all hazardous mountain wave encounters involve turbulence; (2) airspeed fluctuation range, altitude fluctuation range, and any other information needed to adequately describe the effects of the mountain wave activity on the aircraft; (3) parameters for classifying the intensity level of the conditions for a turbulent wave encounter and a smooth wave encounter; and (4) the threshold at which the PIREP for each type of encounter (turbulent or smooth) should be coded as urgent.

[27] Symbols and color codes are typically displayed for defined criteria to provide information about the type of weather phenomenon and its intensity classification.

[28] The actual PIREP was “GTF UA /OV GTF 260035/TM 1640/FL350/TP B752/TB LGT /RM MTN WAVE +20/-40KTS/ZLC.”

3. Improving Dissemination to Reduce Delays and Data Loss

Once a PIREP is submitted to ATC, FSS, or company personnel, the information has value only if it is made available to others in the NAS. Those who receive PIREPs all play an important role in how quickly this information is shared—if it is shared at all. As discussed in the following sections, the NTSB has found that procedural, workload, data-capturing, and distribution issues have inhibited PIREP dissemination and introduced inaccuracies and that some of these problems are exacerbated by a lack of efficient systems and software tools. In some cases, these deficiencies have adversely affected the safety of flight operations and/or resulted in the loss of data for other NAS users.

3.1 Handling by Air Traffic Control

Air traffic controllers routinely provide PIREP services and, under certain weather conditions, are required to solicit PIREPs.[29] Upon receiving a PIREP, a controller has a responsibility to disseminate that information locally and to the NAS, as appropriate. However, as outlined in FAA Order 7110.65W, "Air Traffic Control," paragraph 2-1-1, a controller's primary responsibility–whether the position is at an en route, terminal radar approach control (TRACON), or tower facility–is maintaining air traffic separation, which should be prioritized over additional services. FAA Order 7110.65W, paragraph 2-1-2, "Duty Priority," states, in part, that controllers must "[g]ive first priority to separating aircraft and issuing safety alerts…. Good judgment must be used in prioritizing all other provisions of this order based on the requirements of the situation at hand." The order notes that controllers must first perform the action that, in their judgment, is the most critical from a safety standpoint.

In complying with the provisions of FAA Order 7110.65W, each facility may develop its own standard operating procedures, reflective of its own equipment and staffing, to accomplish these directives. The NTSB notes that different procedures at different facilities can affect how PIREPs are processed into the NAS. Generally, urgent PIREPs and those considered "significant" are subject to handling procedures intended to expedite their dissemination.[30] En route facilities

[29] FAA Order 7110.65W, paragraph 2-6-3, states, in part, that air traffic controllers are required to solicit PIREPs when conditions are reported or forecast to include ceilings 5,000 ft or below, visibility (surface or aloft) 5 miles or less, thunderstorms and related phenomena, light or greater icing, moderate or greater turbulence, windshear, volcanic ash clouds (or detection of sulfur gases associated with volcanic activity), and (for terminal facilities only) when braking action advisories are in effect. The order states that the controller should obtain the PIREP directly from the pilot (unless the PIREP was requested by another facility, in which case the controller may instruct the pilot to deliver the report directly to that facility).

[30] FAA Order 7110.65W, paragraph 2-6-2, states, in part, that "significant PIREP information includes reports of strong frontal activity, squall lines, thunderstorms, light to severe icing, windshear and turbulence…of moderate or greater intensity, volcanic eruptions, volcanic ash clouds, detection of sulfur gases…in the cabin, and other conditions pertinent to flight safety."

relay their operationally significant PIREPs to the weather coordinator.[31] In the terminal environment, the controller relays operationally significant PIREPs to other facility personnel, FSS specialists, or other affected terminal or en route facilities (such as military, nonFAA, or other nonfederal facilities). Some routine PIREPs, however, may not be disseminated at all: the NTSB's investigation of a February 2015 accident revealed that the Fort Worth ARTCC, according to the front line manager, did not disseminate null or other PIREPs described as "containing no significant weather information." This is unfortunate, given that a meteorologist at the CWSU associated with the Fort Worth ARTCC stated that null PIREPs are important for the CWSU's work.[32]

Procedures for how PIREPs are entered into a data system for dissemination can also vary by facility (or at different times within a facility, depending on which positions are staffed at which hours). In addition, the data systems used by different facilities vary, some are cumbersome for entering PIREPs, and, in some cases, separate systems are used for disseminating the information within the facility versus outside the facility. In addition, some methods (such as sending a general information message via the flight data input/output [FDIO] system) can result in nuisance PIREP alerts for personnel outside the geographic location for which the PIREP is relevant (NTSB 2016a, 97).

Some facilities relay PIREPs verbally via telephone to affected adjacent facilities or FSS for entry, and the procedures used at some facilities may call for hand-written PIREPs to be hand carried to staff at another position (including, at some ARTCCs, to CWSU personnel) who can enter it in the facility's system for dissemination; some facilities do not specify who carries the PIREPs or when. At the NTSB's June 2016 forum, the National Air Traffic Controllers Association (NATCA) weather representative referred to the hand-carrying process as "sneakernet" and noted that there is no uniformity in procedures across facilities (NTSB 2016a, 96, 98).

In short, systemwide, the path that PIREP information reported to ATC may take before becoming available to the NAS, if at all, can vary from facility to facility, different processing procedures may apply, and operational factors that may affect the duty prioritization are unpredictable. The procedural issues identified generally fall into four categories: noncompliance with solicitation requirements, inadequate dissemination of both urgent (hazardous weather) and routine weather information, data-entry errors, and inappropriate consolidation of multiple reports.

[31] En route facilities have a weather coordinator who advises center, tower, and TRACON personnel about significant weather that may affect their areas of responsibility. The weather coordinator is an FAA traffic management person who works jointly with NWS meteorologists in the CWSU. The role of NWS meteorologists in the CWSU is to provide weather support to ARTCC air traffic operations. In a letter dated March 14, 2017, the FAA indicated that it had "recently completed" revising the recurrent training curriculum for weather coordinators to emphasize the collection and dissemination of PIREPs. For more information, see the docket for this report (NTSB case number DCA15SR001).

[32] For more information, see the Air Traffic Control Specialist's Report for NTSB case number CEN15LA137.

3.1.1 Procedural Issues

3.1.1.1 Noncompliance with Solicitation Requirements

Solicitation is an important component of increasing PIREPs to improve weather products. One researcher found that 49% of the 189 GA pilots surveyed indicated that the idea of submitting a PIREP does not occur to them while they are flying (Casner 2010). However, pilots typically respond with a PIREP when prompted by a direct request from a controller or FSS specialist. As discussed in section 2.1.1, PIREP solicitation efforts were part of the Alaska Flight Services PIREP Improvement Initiative that documented an increase in PIREPs.

During the NTSB's investigation of an February 2015 accident in Andrews, Texas, we found that the Fort Worth ARTCC controller handling the flight did not solicit PIREPs during weather conditions that met the criteria to mandate solicitation from arriving and departing aircraft.[33] The controller, who was performing approach control duties for the accident pilot's destination airport because the applicable approach control facility was closed for the evening, did not solicit PIREPs from the accident airplane's pilot or from the pilot of an airplane that landed at the accident airport just before the accident flight. During an interview, a front line manager for the facility stated that he had "numerous" discussions with employees regarding approach control procedures and PIREP solicitation. He noted that each front line manager was required to complete one operational skills assessment per month for an employee, with weather dissemination and PIREP solicitation as a special emphasis item. However, a controller at the same facility observed that PIREP-solicitation procedures at that facility might not be done "by the book."

Deficiencies in PIREP solicitation were also discovered during the investigation of a fatal accident involving a Piper PA-32RT-300T airplane that crashed in the vicinity of thunderstorm activity near Hugheston, West Virginia, in April 2014. Although PIREP-handling issues were found to be unrelated to the cause of the accident, the NTSB found that the Indianapolis ARTCC controller who was handling the accident flight and others did not solicit or disseminate any PIREP information during weather conditions that mandated such service.[34] The controller handling the flight described his air traffic workload at the time as heavy and complex; the accident flight alone received several communications from the controller who also monitored the flight's progress, observed deviations, and asked the pilot repeatedly if he needed assistance. However, the investigation also found that the supervisor on duty did not comply with requirements of FAA Order JO 7210.3Z, "Facility Operation and Administration," chapter 2, "Administration of Facilities," which stipulate that supervisors "maintain situational awareness…of traffic activity and operational conditions in order to provide timely assistance to specialists" and "ensure available resources are deployed for optimal efficiency." The supervisor in this case was not performing any other duties while sitting nearby but was unaware of the developing situation with the accident flight or the controller's workload. This example suggests that, during times of high controller workload, proper supervision is needed to allocate assistance and resources to ensure that required tasks (such as soliciting and disseminating PIREPs) are covered.

[33] The reported ceiling condition at the airport about the time of the accident was overcast at 700 ft. For more information about this accident, see NTSB case number CEN15LA137.

[34] For more information about this accident, see NTSB case number ERA14FA192.

During the NTSB's June 2016 forum, the air traffic operations manager from the Kansas City ARTCC noted that, when adverse weather conditions are present and air traffic is busy, controllers are busy, too, and their priorities begin to accumulate. He noted that aircraft separation is the main priority and weather dissemination (including PIREPs) is next, but the gap between the two duties widens when controllers must focus on separation. In this type of situation, soliciting PIREPs becomes difficult. He said that controllers rely on pilots to report weather conditions they have just flown through; however, processing such reports can be resource draining when controllers are managing waves of traffic. He suggested that automation that could enable controllers to collect information directly from their displays would be helpful in collecting and disseminating PIREPs (NTSB 2016b, 212-214). Improved efficiency tools are needed because the high controller workload due to the effects of adverse weather on traffic flow results in reduced PIREP processing during times when PIREPs are needed most to ensure flight safety in the NAS. Workload, however, is not always a limiting factor; other issues can affect a controller's PIREP-solicitation performance.

3.1.1.2 Inadequate Dissemination of Weather Information

Although FAA orders allow for flexibility and judgment regarding how controllers prioritize their tasks, the NTSB has investigated cases in which PIREP handling was inconsistent with good judgment and/or not in compliance with procedures. In August 2015, the flight crew of an Airbus A320-211 declared an emergency after the airplane encountered hail during cruise flight, which resulted in a shattered windshield and airframe damage.[35] The flight crew diverted and landed the airplane safely, and the 124 people onboard were not injured.

The investigation discovered that the company dispatcher did not provide the flight crew with the most current turbulence and thunderstorm activity information that had been issued by the airline, both of which indicated potential thunderstorm activity along the route of flight. And, although a flight crewmember asked the Denver ARTCC controller repeatedly for PIREPs about the status of a "hole" in a line of convective weather on his route, the controller did not provide him with the PIREPs he received; these included a report from the crewmember of a Boeing 737 who had just transited the gap between thunderstorms and advised that he "wasn't sure if anyone was going to want to go through there behind us" and from a crewmember of another transport-category airplane who had flown through the gap between the two areas of thunderstorms and advised the controller to "let the guys behind us know that the atmosphere warms up dramatically, we've got a +28° ISA deviation, and our computer's thinking we're falling out of the sky."[36] The NTSB determined that contributing factors to the incident were the company dispatcher's failure to provide complete and timely weather information to the incident flight crew and the Denver ARTCC controller's failure to provide the flight crew with significant PIREP information.

Also, the PIREP for the hail encounter itself recorded a time that was about 11 minutes after the actual weather encounter, and it was coded as a routine report, even though it contained severe turbulence and hail information, both of which meet the criteria for an urgent PIREP. As

[35] For more information about this incident, see NTSB case number OPS15IA020.

[36] By "ISA deviation," the pilot was referring to a computation of actual temperature minus the International Standard Atmosphere temperature.

mentioned previously, urgent PIREPs receive priority dissemination; thus, misclassification of the PIREP type hinders the timely dissemination of the information (and also affects the depiction of the PIREP on graphical weather products).

In March 2012, a Learjet 35A encountered severe in-flight icing conditions during approach to land in Anchorage, Alaska, that exceeded the capabilities of the airplane's windscreen anti-ice systems, and the airplane's windscreen abruptly iced over.[37] As a result, the flight crew lost all forward visibility, and the airplane veered off the runway during landing and came to rest in a snow bank. (Figure 3 shows the iced-over windscreen of the incident airplane.)

Figure 3. Photograph of a Learjet 35A with ice-covered windscreen (NTSB case number ANC12IA024).

The investigation found that, about 15 minutes before the airplane encountered the severe icing conditions, the Anchorage approach controller who was handling the Learjet 35A had been advised by the tower controller at Elmendorf Air Force Base (about 7 miles northeast of the incident airport) that a pilot of an F-16 (single-engine military jet) conducting an approach to Elmendorf reported "severe icing on final" and initiated a go-around to "wait until his windshield…cleared." The Elmendorf tower controller used good judgment in sharing the severe icing PIREP with the Anchorage facility; however, the Anchorage approach controller did not relay the urgent PIREP to the Learjet flight crew (or the pilot of another aircraft operating near Anchorage), which the NTSB found to be a contributing factor to the incident.

An FAA representative indicated that the approach controller who handled the Learjet flight did not recognize the significance of the PIREP and its relevance to operations under his jurisdiction. The FAA representative noted that facility personnel might have become complacent about handling and disseminating icing reports due to the volume of such reports. About 6 months

[37] For more information about this incident, see NTSB case number ANC12IA024.

after the Learjet incident, a pilot of an aircraft involved in an anomalous, rapid loss of altitude provided an urgent icing PIREP to an Anchorage approach controller that was not given to the Anchorage ARTCC or otherwise disseminated (NTSB 2016a, 50-53).[38] According to the Anchorage ARTCC quality control manager, after that event, the facility took action to improve its culture and procedures regarding PIREPs. (These actions are discussed in section 3.1.3.)

An NTSB investigation of a June 2012 accident involving a Learjet 60 in Aspen, Colorado, highlighted an instance in which a PIREP containing hazardous weather information (for LLWS) was disseminated to local traffic, including the accident flight crew, but was not processed for distribution to the NAS.[39] This PIREP, which included a report of a 15-knot loss of airspeed on short final approach, met the classification criteria for an urgent PIREP and should have received priority handling for dissemination so that other pilots, controllers, and aviation weather forecasters could benefit from the information. PIREPs of LLWS, especially those that provide specific information on the altitude of the encounter and losses or gains in airspeed, are of particular importance to forecasters when validating actual conditions against the data they use to support their development of TAFs and AIRMETs.[40]

During the NTSB's investigation of a fatal accident involving a Cessna 500 in Derby, Kansas, in October 2013, we found that, during a 2-hour span, the Kansas City ARTCC received four routine PIREPs (three were reports of light rime ice encountered at different altitudes from GA pilots, and one was a report of broken cloud cover) that were recorded by hand on PIREP forms, but only two of the reports were publicly disseminated.[41] A representative from this facility stated that controllers usually enter PIREPs directly into the en route information display system (ERIDS) and verbally notify the front line manager or controller-in-charge, but facility procedures alternatively allow controllers to record the report by hand on the PIREP form and give it to the front line manager or controller-in-charge for processing.[42] The facility representative stated that controllers might prefer to use the form during times of high workload because it requires less time than entering the information into ERIDS. The representative stated that PIREPs might not be disseminated because the information was considered "not pertinent," or the information was not forwarded to the front line manager for processing. According to the representative, "pertinent PIREPs are those that are required by FAA Order 7110.65 paragraph 2-6-3 (a)." (That paragraph defines the conditions that require PIREP solicitation, which include ceilings at or below 5,000 ft and icing of a light degree or greater.) The icing conditions (all of which were encountered at

[38] At the time, the procedure at Anchorage approach involved faxing PIREPs to the FSS for dissemination.

[39] The reason that the urgent PIREP was not disseminated was not determined. For more information about this accident, see NTSB case number CEN12LA345.

[40] Per NWS Instruction (NWSI) 10-813, WFO forecasters must include forecasts of nonconvective LLWS in their TAFs. Similarly, NWS forecasters at the AWC are responsible for producing AIRMETs that identify nonconvective LLWS below 2,000 ft above ground level, per NWSI 10-811.

[41] The pilot flew the Cessna 500 into severe icing and IMC about 10 minutes after takeoff and subsequently lost control of the airplane. The NTSB determined that the probable cause of the accident was, in part, the "airplane's encounter with severe icing conditions, which resulted in structural icing, and the pilot's increased workload and subsequent disorientation while maneuvering in instrument flight rules (IFR) conditions with malfunctioning flight instruments, which led to the subsequent loss of airplane control." For more information about this accident, see NTSB case number CEN14FA009.

[42] According to FAA Order JO 7210.3Z, chapter 10, ERIDS is a "real-time, interactive, electronic information display system that is used as a replacement for paper sources of information." It provides facility personnel with access to PIREPs, weather data, airspace charts, and other sources of ATC information.

different altitudes) reported in the PIREPs that were not disseminated met the facility's criteria for "pertinent."

During an interview with NTSB investigators, the Kansas City ARTCC representative stated that the facility places its greatest emphasis on urgent PIREPs. When an urgent PIREP is entered, the facility's front line manager notifies the CWSU, and the urgent PIREP is both entered into the Aeronautical Information System-Replacement (AIS-R) for NAS distribution and distributed to facility personnel via ERIDS and another messaging system.[43] The procedure is for "pertinent" PIREPs to be disseminated within the facility via ERIDS and to the NAS via AIS-R. Routine PIREPs are to be processed through the flight data unit via ERIDS, which may result in a delay of a few minutes; the flight data unit personnel enter the routine PIREP into AIS-R and redistribute it to facility personnel via ERIDS. The facility representative did not know how often (or how many) PIREPs were not disseminated because PIREP tracking was not required at that facility.

The investigation of a February 2014 fatal accident involving a Commander 690C near Bellevue, Tennessee, revealed that none of the 13 PIREPs that were verbally submitted to Nashville TRACON personnel (most of which reported light-to-moderate rime icing conditions) were documented on a PIREP form or shared among the facility's sector personnel. Only one PIREP was disseminated to the NAS.[44] From about 90 minutes before to about 10 minutes after the accident, the Nashville ARTCC west sector received seven PIREPs, the east sector received one, and the tower received five. The west sector controller (who had been handling the accident flight before a position relief change) recalled overhearing the east sector controller receive PIREPs about icing conditions but believed that those reports were pertinent only to the aircraft in the east sector.

Although the lack of PIREP dissemination was not found to be a factor in the cause of the accident, it may have inhibited the issuance of an icing weather advisory for the area. The investigation found that no AIRMETs for icing conditions had been issued before or after the time of the accident. The forecaster who was on duty stated that the first PIREP of moderate icing he saw for the Nashville area came in around the time of the accident, which he treated as an isolated report because all the other reports that he saw indicated only light icing conditions. He did not have the benefit of knowing about the two reports of moderate icing received by the tower or of the other icing PIREPs that were not distributed.

Nashville TRACON personnel stated that the process for PIREPs (for both TRACON and tower controllers) was to complete the PIREP form and give it to the supervisor, who would then communicate the PIREP to LMFS for distribution to the NAS. However, a controller at the facility estimated that "20 to 30 percent of the time," LMFS personnel would not answer the phone or were otherwise unavailable to receive the PIREP information. Since the time of this accident, the

[43] According to an FAA AIS-R training document, AIS-R is a web-based, automated means for the collection and distribution of PIREPs, meteorological aerodrome reports, flight plan data, and other operational information. It is owned, operated, and maintained by the FAA and is used by ARTCCs, TRACONs, ATC towers (both federal and nonfederal), and other facilities.

[44] The tower controller, who had received two such reports, relayed only one PIREP of moderate rime ice to a controller staffing the local flight data position. For more information about this accident, see NTSB case number ERA14FA112.

FAA issued a nationwide policy change to remove LMFS from each TRACON's PIREP-dissemination process (see the next section for more information).

3.1.1.3 Data-Entry Mistakes

Reviews of daily PIREP submissions and examples from accident and incident investigations show that typographical, formatting, and other input mistakes are common. Currently, these types of mistakes are made primarily by the ground personnel who input PIREP information received verbally (typically air traffic controllers, FSS specialists, or company dispatchers); however, pilot use of data-input systems is increasing. Errors such as providing an icing modifier for a turbulence report ("TB MOD RIME" for turbulence moderate rime), coding an urgent PIREP as a routine report, including extra spaces or symbols in a location text element, or other typographical errors ("KGT" instead of "LGT" for "light," or "MDT" instead of "MOD" for "moderate") can severely reduce a PIREP's usefulness.

For example, a CWSU meteorologist pointed out that the AWC website, which displays graphical depictions of PIREP information, cannot process PIREPs that contain typographical or formatting errors. Thus, PIREPs containing such errors may not be disseminated to the NAS. The meteorologist also stated that some urgent PIREPs—including one that reported a funnel cloud—that appeared in a text-based system were not displayed on the AWC website due to formatting issues. Further, because ATC procedures place a higher priority on urgent PIREPs, the dissemination of an urgent report that is not properly coded as such may be delayed, and it will not trigger a special alerting feature that notifies the AWC that an urgent PIREP has been filed. Although PIREPs can be subject to a review and correction process, this requires manual effort, and reviewers may not catch all the errors or be able to interpret the original report.

Some data-input systems are better than others at minimizing the potential for input errors; this issue was highlighted when PIREP errors began to surface after a recent FAA policy change that required terminal facility air traffic controllers to input PIREPs directly into the AIS-R system. Terminal facilities previously submitted PIREPs to LMFS for entry and dissemination, but, effective March 1, 2016, controllers were required to enter the PIREPs into AIS-R themselves.[45] The new policy stated that controllers in operational positions would pass PIREPs to the front line manager or controller-in-charge, who then would assign someone to enter the PIREP into AIS-R; when timely entry of a PIREP was not possible, the PIREP was to be forwarded to the overlying ARTCC flight data unit for dissemination. The FAA provided a computer-based training module to controllers on how to use the AIS-R system. However, CWSU personnel reported that, since the adoption of the new policy, multiple PIPEPs entered directly into AIS-R by ATC facilities have contained errors. For example, urgent reports have been coded as routine, a FL that translated to "400,000 feet" was reported, and the text elements of some PIREPs were transcribed using full words, rather than the abbreviated codes upon which other systems rely for display processing.

[45] The change was originally announced in an August 19, 2015, FAA memorandum, which stated that controllers at terminal facilities (including FAA contract towers) would have access to the AIS-R web-based system starting on December 21, 2015, to enter PIREPs for widespread dissemination to the NAS. According to the memo, the change was part of efforts to reduce the costs associated with providing flight services in the NAS. The memo noted that facility air traffic managers "must establish procedures for the prompt collection and dissemination of PIREP information" and that all affected personnel must complete a specified AIS-R training course before the new policy, announced in FAA Notice N JO 7110.705, took effect on March 1, 2016.

The CWSU personnel reported that they communicated with some of the ATC facilities about the problems and have seen some improvements since then.

Although new user unfamiliarity with AIS-R likely contributed to some of the PIREP errors, a review of the AIS-R data-entry interface found that it was not designed to prevent user errors. For example, input fields for many of the PIREP elements require the user to type in the information as a free-text entry. Although free-text data fields provide flexibility for users to input unrestricted information when needed (such as in the "remarks" field), they present opportunities for typographical errors in data fields that need to capture one of only a few possible standard options (such as icing type or intensity codes). Data fields that need to capture only one identifier out of a limited set of standard choices may be better served by an interface that enables digital data entry through drop-down menus and/or other error-prevention mechanisms that allow the user to select only from options that logically apply (such as turbulence modifiers only when turbulence is selected). The use of standard computer interface techniques for the entry of coded data can reduce the likelihood of data-entry errors, reduce the human effort required to enter the data, and improve the speed of data entry.

Once a PIREP is entered into AIS-R, there is currently no automation that allows it to be seen by other controllers (NTSB 2016a, 100); to share a PIREP electronically, a controller must also enter it into the FDIO system and disseminate it as a general information message. At the NTSB's June 2016 forum, the NATCA weather representative noted that "having someone else touch that PIREP at least once, and sometimes as many as four or five times, is not an efficient way" to collect and disseminate information (NTSB 2016a, 101). Thus, an additional level of automation that could reduce the potential for errors would be the capability to capture aircraft information that is available on the controllers' displays (such as time, aircraft type, location, and FL), automatically populate it into an electronic PIREP, and disseminate the PIREP to other controllers and to the NAS. Some NextGen technologies, such as the en route automation modernization (ERAM) platform, could provide the foundational infrastructure for future automation capabilities for air traffic controllers.[46]

The FAA has recognized the importance of data-entry and dissemination solutions and implemented them for other essential aeronautical information, such as notices to airmen (NOTAMs). The FAA modernized its federal NOTAM system to "digitize the collection, dissemination, and storage of NOTAMs" with "the goal to create a single, authoritative source for NOTAM entry and dissemination to improve efficiency, safety, and data quality of NOTAM information."[47] The federal NOTAM system interface for data entry uses established techniques for minimizing data-entry errors and easing the associated human burden for entering the data, such as drop-down menus and template-driven event scenarios that allow rules to be applied against the various data elements. Use of these features in the NOTAM system not only helps

[46] The ERAM platform, which was completed in 2015, is a new computer system designed to increase airspace capacity and improve safety and efficiency. According the FAA's ERAM web page (www.faa.gov/air_traffic/technology/eram/), "ERAM processes flight and surveillance radar data, enables efficient controller-pilot communications, generates detailed display data to air traffic controllers, and provides the platform for digital data sharing and trajectory-based operations."

[47] For more information about the FAA's NOTAM manager application, see the FAA's federal NOTAM system web page (https://notams.aim.faa.gov/).

prevent errors but also formats the information for use with a common exchange model to ensure that downstream systems can process it.

The NTSB concludes that established user-interface design practices for automated systems for entering coded information, such as those that the FAA applied to improve the collection and dissemination of its digital NOTAM data through a common exchange model, could produce similar improvements in the process by which air traffic controllers collect and disseminate PIREP data. Therefore, the NTSB recommends that the FAA provide air traffic controllers with automated PIREP data-collection tools that incorporate design elements to prevent input errors, increase quantity, and improve the timeliness of PIREPs disseminated to the NAS. The NTSB further recommends that the FAA incorporate automation technology that captures data elements from air traffic controllers' displays, including aircraft type, time, location, and altitude, to automatically populate these data into a PIREP-collection and -dissemination tool that will enable controllers to enter the remaining PIREP elements and disseminate PIREPs through a common exchange model directly to the NAS.

3.1.1.4 Consolidating Multiple PIREPs

Consolidating or summarizing the information from several individual PIREPs into a single PIREP for dissemination is another common handling problem that affects the usefulness of submitted PIREPs. This practice presumably evolved as a time-saving shortcut, particularly considering some of the cumbersome procedures and data systems for processing PIREPs. However, such consolidation is not appropriate per any training or guidance controllers receive (training is discussed in section 3.1.2); however, the practice appears to have become normalized to some extent because these types of consolidated reports appear daily in the NAS.

In one example, a controller filed a single urgent PIREP for moderate-to-severe turbulence from "numerous" types of aircraft.[48] In another example, a controller filed a single PIREP for moderate turbulence for "multiple" aircraft types at FL240.[49] A review of other PIREPs reported for the surrounding area at later times revealed a report of severe turbulence experienced in a regional jet between FL260 and 280 and moderate-to-severe turbulence experienced in an Embraer 500 between FL190 and 210. The remarks for the latter report noted, "also experienced by a Boeing 737."[50] In another example, a controller filed a single urgent PIREP for light-to-moderate turbulence and LLWS with +/-5 to 10 knots on the final approach to the runway for "all types" of aircraft.[51] (This PIREP also does not specify whether the airspeed fluctuation

[48] The actual PIREP was "PIT UUA /OV PIT/TM 1024/FLAT/TP NMRS A/C/TB MOD-SEV/RM FL/AT OR BELOW FL230."

[49] The actual PIREP was "JAN UA /OV MHZ - IGB - MEI - MHZ/TM 1405/FL240/TP MULTIPLE/TB MOD 240-340/RM ZME."

[50] The actual PIREPs were "JAN UUA /OV MHZ 045050/TM 1416/FL260/TP CRJ2/TB SEV 260-280/RM ZME" and "FTW UUA /OV TTT240012/TM 1600/FL190/TP E55P/TB MOD-SEV FL190-210/RM ALSO RPTD BY B737 AWC-WEBKZFW."

[51] The actual PIREP was "BJC UUA /OV FA RWY 30R/TM 1545/FL060/TP ALL TYPES/TB LGHT TO MOD/RM LLWS +/- 5 TO 10KTS SHORT FINAL."

was a loss or a gain; however, the pilot may have reported it as "plus or minus," as described in section 2.2.2.1.)

Although controllers may find consolidated reports useful for general situational awareness of hazardous weather areas, the pervasiveness of the practice suggests that they may not realize that consolidating PIREPs omits valuable information such as aircraft type (for example, the distinction between transport-category and GA aircraft is lost), time, and location that pilots and meteorologists need to know for tactical and strategic use. Pilots, for example, need to know the type and location of the reporting aircraft so that they can assess how reported conditions like turbulence and icing may apply to the type of aircraft they are flying, and weather forecasters need to know the number and locations of the reports to determine if advisories need to be issued or revised or forecasts amended.

As stated earlier, weather forecast models that use PIREPs may not import data from PIREPs that are not correctly formatted or coded. In one example, the pilots of two single-engine GA airplanes provided urgent PIREPs of moderate-to-severe turbulence. However, only one PIREP that recorded the location and time for only one of the airplanes was disseminated to the NAS (the other airplane was mentioned in the remarks section of this single PIREP).[52] As a result, only one symbol for a single PIREP appeared on a graphical depiction of the reported turbulence events. At the time of these events, no CWA, AIRMET, or SIGMET was in effect, and no such turbulence was forecasted for that area. Had both urgent PIREPs been input separately, it would have increased the likelihood that a weather advisory would have been issued after the turbulence encounters. Having two PIREPs also would have better assisted researchers in verifying the weather models and hazard identification algorithms. If implemented, the improved PIREP data-collection and -dissemination tools for air traffic controllers recommended in section 3.1.1.3 should help eliminate the practice of consolidating multiple reports.

3.1.2 Training and Guidance

The 2-hour PIREP lesson plan that is part of the FAA Academy's Air Traffic Basics course contains information that explains the purpose of PIREPs and provides procedures for controllers to solicit, code, distribute, and decode PIREPs (FAA 2014c). Among the references listed in the training materials are FAA Order JO 7110.65, "Air Traffic Control"; FAA Order JO 7110.10, "Flight Services"; the AIM; and FAA Form 7110-2 (the PIREP form). The lesson plan provides information and examples to be discussed in a classroom setting to cover the fundamentals necessary to prepare controllers for handling PIREPs. However, given the problems occurring in the operational environment (as described in the preceding sections), the NTSB is concerned that the training provided to air traffic controllers is ineffective at ensuring that PIREPs are being correctly solicited, collected, and disseminated.

One reason for recurring operational problems may be that some of the operational procedures available to controllers are ambiguous or may conflict with other procedures and guidance. Although all of the FAA orders that prescribe procedures for air traffic controllers indicate that controllers should use their best judgment if they encounter situations not covered by

[52] The actual PIREP was "BNA UUA /OV TYS090020/TM 1950/FL100/TP BE36/TB MOD-SEV/RM ALSO BE35."

procedure, information in some of the orders differs to the extent that a controller's response may vary, depending on which reference the controller uses.

For example, FAA Order JO 7210.3Z, "Facility Operation and Administration," chapter 6 (which applies only to ARTCC facilities), indicates that urgent PIREPs will be distributed immediately but does not specify the procedure for routine PIREPs. This discrepancy could be interpreted to mean that dissemination of routine PIREPs is not required. Chapter 10, which applies to terminal ATC facilities, specifies that soliciting and handling PIREPs should be accomplished in accordance with FAA Order 7110.65, which provides criteria for "significant PIREP" information but does not include the criteria for urgent PIREPs. FAA Order 7110.65W provides handling instructions for relaying "pertinent PIREP information" and "operationally significant PIREP information"; however, it does not define or provide guidance about the terms "pertinent" or "operationally significant."

FAA Order JO 7110.10Y, "Flight Services," which is used by personnel "providing air traffic control services," provides more guidance on PIREP encoding than FAA Order 7110.65W or the AIM. (Although the AIM is a resource for pilots, it is listed as a reference in both the training and orders that pertain to ATC, and the AIM itself does not contain complete PIREP-coding guidance, as discussed in section 2.2.2 of this report.) The NTSB notes that now that more ATC personnel are entering PIREPs directly into AIS-R themselves rather than passing the information to LMFS for entry, consistent and comprehensive PIREP-coding guidance is even more important.

Consistency among these training and guidance materials is necessary to ensure that controllers have clear, standardized information indicating the services that they are expected to provide, regardless of which document is referenced. The NTSB concludes that inconsistent and ambiguous information contained in various PIREP guidance and procedures documents for air traffic controllers can lead to confusion and possible errors in PIREP solicitation, documentation, and dissemination. Therefore, the NTSB recommends that the FAA revise FAA Orders JO 7110.65W, "Air Traffic Control"; JO 7110.10Y, "Flight Services"; and JO 7210.3Z, "Facility Operation and Administration," to ensure that the chapters of the orders that address PIREPs include improved and consistent guidance about PIREP coding, handling, solicitation, and dissemination.

Some controllers may not fully understand the importance of all PIREPs to the weather forecasting process, which is likely another reason that PIREP-handling problems are occurring in the operational environment. In response to an NTSB request for information, in April 2016, an FAA representative stated that the PIREP and Weather Dissemination Task Force (more information is in section 3.1.3) expressed this concern and its findings to its recurrent training group; the FAA representative said that the information was then used to structure training for controllers to improve their understanding of the importance of timely solicitation and dissemination of PIREPs.[53]

The NTSB notes that the FAA Academy's Air Traffic Basics course lesson plan does not specify whether scenario-based examples are used to explain to air traffic controllers how meteorologists use PIREPs in deciding to issue a hazardous weather advisory or amend its

[53] For more information, see the docket for this report (NTSB case number DCA15SR001).

geographic area or to explain how common errors and time-saving practices (like consolidating multiple reports into a single PIREP) can render the information practically useless to meteorologists and greatly diminish its usefulness to pilots. As discussed previously, scenario-based examples were used during outreach training for controllers as part of the efforts of the Alaska Flight Services PIREP Improvement Initiative and working group. Efforts that targeted controllers focused on increasing PIREP solicitation and dissemination, which was followed by a measured increase in PIREPs in the NAS. The initial campaign results show that scenario-based training can play a role in fostering an operational understanding of and connection to the information being taught.

The NTSB believes that the successes achieved from previous outreach efforts show that scenario-based education provided in the operational environment can enhance PIREP-handling performance; this type of information could be incorporated into classroom discussions within the context of existing training course lessons. Thus, the NTSB concludes that scenario-based education for air traffic controllers that uses real-world examples can help controllers better understand the importance and uses of all PIREPs, which may foster a safety culture that motivates controllers to reduce PIREP-handling omissions and errors. Therefore, the NTSB recommends that the FAA review and revise air traffic controller training to ensure that it provides scenario-based education, relevant to the controller's specific facility type and location, that includes real-world examples that demonstrate the value of both fair-weather and adverse-weather PIREPs to weather forecasters and that shows how location inaccuracies and common collection and dissemination errors, including the consolidation of multiple PIREPs, adversely affect the usefulness of the reports to all NAS users.

3.1.3 Efforts to Improve the PIREP-Solicitation and -Dissemination Process

Over the years, the FAA has participated with various task groups that have attempted to address PIREP-processing problems. In 2008, the FAA, AOPA Air Safety Foundation (currently the AOPA Air Safety Institute), and NWS launched "Project PIREP," which included a 90-day demonstration with the goal of collecting more and better reports to help the AWC more accurately identify areas conducive to airframe icing. During the demonstration, air traffic controllers in the Seattle ARTCC and surrounding TRACONs solicited at least three PIREPs an hour during specified weather conditions as directed by the AWC. The FAA reported in the May/June 2008 issue of *FAA Aviation News* magazine that "the organizations involved in this demonstration effort will review, summarize, and analyze the results in order to enhance the quantity and quality of PIREPs on a nationwide basis" (FAA 2008, 3). However, the FAA never published any information about the project outcomes.

The FAA has provided some information about its more recent PIREP-related initiatives, such as the PIREP and Weather Dissemination Task Force, which was convened in October 2014 and led to FAA's identification of "weather dissemination" (including PIREPs) among its "Top 5" list of hazards to address for fiscal year 2015.[54] In response to an NTSB request for information regarding the results of the task force's efforts, in April 2016, an FAA representative stated that one outcome was for all terminal facilities to review and update their standard operating

[54] The task force included the FAA, NWS, NATCA, and AOPA.

procedures. The purpose of this effort was to ensure compliance with the requirement in FAA Order 7210.3Z to have established procedures for the prompt collection and dissemination of weather products and for the air traffic managers to identify a central source responsible for carrying out the procedures. The FAA representative stated that the task force also submitted a proposal to the FAA Audits and Assessments office to conduct random audits to verify that terminal facilities are in compliance with these requirements.[55] More recently, FAA has designated "Inflight Pilot Report Collection and Dissemination" as one of three internal agency "significant safety issues" for fiscal year 2017.[56]

The NTSB notes that although the FAA has audits and compliance verification procedures, it is unclear what corrective measures facilities will take if audits detect PIREP-handling deficiencies. At the NTSB's June 2016 forum, the Anchorage ARTCC quality control manager stated that most facilities would not pass an audit regarding PIREP collection and dissemination and that the Anchorage center had not passed one for more than 20 years until 2015 (NTSB 2016a, 53). As described in section 3.1.1, several NTSB investigations involving ATC facilities in different parts of the country found that PIREPs of even hazardous weather were not processed or solicited as required; at least one facility had no means to determine how often or how many PIREPs were not disseminated in accordance with procedures. The NTSB is concerned that, because PIREP-related tasks are relatively low priority, ATC facilities may not take PIREP-handling deficiencies seriously or emphasize process improvements. The NTSB is encouraged by the FAA's commitment to emphasizing PIREP collection and dissemination as a safety issue priority for fiscal year 2017, which includes advising FAA executives of identified risks and potential controls to help address these issues. The NTSB notes that one method of identifying potential controls is to review the successes of facilities that have either improved or consistently performed well their PIREP-handling responsibilities.

Some facilities that handled an aircraft involved in an accident or incident sought ways after the event to improve their procedures. For example, after the February 2014 Commander 690C accident (discussed in section 3.1.1.2), the Nashville TRACON implemented changes that included instructions for controllers to solicit more PIREPs and a means for having new PIREPs flash on the controllers' displays. Focused improvement initiatives began at the Anchorage ARTCC after the March 2012 Learjet 35A incident and the facility-investigated event in September 2012. According to the Anchorage ARTCC quality control manager, the solution involved, in part, changing the culture in the operation. The facility brought in pilots to speak to the controllers and help them understand how pilots use PIREPs. The facility also implemented other local PIREP improvement initiatives, engaged technical training leaders and safety personnel in air traffic, and developed a worksheet that provided the controllers direct feedback on PIREP-handling performance (NTSB 2016a, 53-55).

As discussed previously, the Alaska Flight Services PIREP Improvement Initiative was a multifaceted effort that involved Alaska FSSs, ATC facilities, and pilot groups and was followed by a measurable increase in PIREPs. The Anchorage ARTCC quality control manager attributed

[55] For more information, see the docket for this report (NTSB case number DCA15SR001).

[56] According to an FAA representative, the "significant safety issues" process is an annual FAA effort to identify and prioritize aviation hazards and advise FAA executives of these risks and possible controls, in accordance with FAA Order 8040.A, "Safety Risk Management Process."

that project's success to leadership within the facility, within NATCA, and from the management team (NTSB 2016a, 68).

Some ATC facilities, however, consistently provide numerous PIREPs to the NAS. For example, an AWC forecaster noted that, during weather conditions that meet the criteria for IFR, Boston air traffic controllers routinely provide at least one PIREP per hour for NAS dissemination that includes cloud base and tops information; the forecaster said that this information is helpful for IFR AIRMET forecasting. The Anchorage ARTCC quality control manager stated that controllers at his facility incorporate PIREP solicitation into their workload, requesting PIREPs every 15 minutes, but noted that Anchorage does not face the same traffic density challenges as some of the busier centers like Atlanta, Chicago, or Los Angeles (NTSB 2016a, 210-11). The NATCA weather representative noted that the performance at facilities that process large numbers of PIREPs can be attributed, in part, to management leadership; localized initiatives and procedures; and a proactive, collaborative culture (NTSB 2016a, 100-101, 155, 190). The Chicago CWSU manager reported that he has reached out to other centers to learn about their best practices and observed that different centers have different leadership and, therefore, different solutions that work for them; he noted that the common goal is to increase the number of PIREPs (NTSB 2016a, 212-213).

These examples of performance improvements suggest that facilities that are highly motivated to improve PIREP processing have discovered ways to accomplish that goal. Different types of facilities (en route, TRACON, and tower) inherently have different procedures, staff positions, and equipment, and different workload scenarios require judgment and task prioritization. Also, facilities of the same type likely have procedures that vary from one facility to the next. Therefore, no one solution could work for every facility or even each type of facility.

The NTSB concludes that ATC facilities that consistently solicit and disseminate a high volume of quality PIREPs have developed internal monitoring processes, self-evaluation criteria, leadership and cultural change initiatives, and/or procedural solutions that like facilities can learn from and adopt—or adapt—to improve PIREP-handling performance. NATCA, which has served on past working groups to improve PIREP solicitation and dissemination at ATC facilities, can provide valuable experience and information to help determine best practices for future improvements. For example, the FAA partnered with NATCA in March 2016 for an outreach campaign, "Take a Stand for Safety: Weather—Complete the Picture," to encourage controllers to improve their dissemination of weather information, including soliciting PIREPs and using them to "save lives on a daily basis."[57] Therefore, the NTSB recommends that the FAA, in collaboration with NATCA, develop and distribute to all ATC facilities best practices guidance for the solicitation and dissemination of PIREPs for each type of ATC facility. The NTSB also recommends that NATCA work with the FAA to develop and distribute to all ATC facilities best practices guidance for the solicitation and dissemination of PIREPs for each type of ATC facility.

[57] For more information, see FAA correspondence dated March 14, 2017, in the docket for this report (NTSB case number DCA15SR001).

3.2 Operator Handling

Pilots who fly for operators that use flight support personnel (such as dispatchers, flight coordinators, and others) may file their PIREPs directly with these company personnel, either verbally or through ACARS, rather than with ATC or FSS personnel. (Also, some operators require their dispatchers to solicit PIREPs from flight crews.) Some operators recognize the importance of sharing PIREPs to the NAS to enhance flight safety and readily submit their PIREPs for public dissemination; however, their personnel have limited options for submitting these PIREPs to the larger community of NAS users. Other operators choose to keep the PIREPs provided by company flight crews "proprietary," sharing them only with other company personnel. Both of these aspects of operator PIREP handling are discussed below.

3.2.1 Proprietary Practices that Inhibit Dissemination

During discussions with NTSB staff, an employee of an operator that provides 14 *CFR* Part 91, 91K, and 135 flights at smaller airports indicated that, during winter months, company personnel may make hundreds of telephone calls per day to airports to verify or update surface weather conditions before, during, and after flights. Although this operator chooses to keep its PIREP information proprietary, the employee noted that more PIREPs from other operators for runway/surface conditions would be helpful. For operations conducted at nontowered airports, unmonitored remote landing sites, or at towered airports during tower closure hours, braking action and runway condition reports filed as PIREPs may be the only source of such information.[58]

As another example, an NTSB accident investigation revealed that the flight coordinators for a 14 *CFR* Part 135 operator involved in a July 2015 fatal accident near Juneau, Alaska, routinely refer to PIREPs and other weather products when briefing company pilots before the first flight of each day. Although these flight coordinators provide PIREP information to company pilots and encourage them to speak with other company pilots about weather conditions (for example, if one pilot were headed to an area from which another had just departed), the flight coordinators do not share the company PIREPs that they receive to others in the NAS.[59] Both of these operators provide air service to remote areas that have relatively few weather observation sources; therefore, PIREPs from these operators would be valuable not only to other pilots for avoiding weather hazards but also to weather forecasters for issuing advisories and improving forecasts in areas that have few observation stations.

The FAA authorizes some certificated operators to use approved private weather services (either staffed by company personnel or provided by a commercial vendor), and some of these

[58] At larger airports (like those certificated under 14 *CFR* Part 139), braking action reports can be submitted to ATC personnel by pilots or by airport management personnel who take surface friction measurements. ATC tower personnel disseminate the information to arriving and departing traffic, and runway closures are required until reported hazards are resolved (for example, until a reported "nil" braking action condition no longer exists). The following is an example of a braking action report filed as a PIREP from a flight that landed after the control tower's operating hours: "PAKN UA /OV PAKN/TM 0430/FL007/TP SF34/SK CIG 007/WX 1/TB NEG/IC NEG/RM RWY 12 BRAKING ACTION POOR=."

[59] Submission possibilities currently include telephoning FSS or using a web-based PIREP-submission tool or application (section 3.2.2 discusses the need for operators' capabilities to directly submit PIREPs for dissemination to the NAS). For more information about this accident, see the docket for NTSB case number ANC15FA049 (the accident investigation was not completed at the time of this report, but the docket is open for public view).

weather service providers share the PIREPs received from client pilots within only the clients' company or with the company and other service subscribers.[60] For example, an NCAR review of a turbulence event involving a Part 121 operator revealed that the operator had access to more PIREPs than were available in the NAS, including one PIREP that contained a "mayday" with the reported weather phenomena. This "mayday" PIREP originated from another air carrier that apparently subscribed to the same weather service that maintained information as proprietary for subscribers.

Clearly, any company PIREP that includes a "mayday" represents an immediate safety of flight issue for others in the NAS. The NTSB recognizes that, in a competitive market, commercial weather service providers may wish to keep some of their unique services and products proprietary (commercial services, some of which may require operator investment in specialized aircraft equipment, are discussed further in section 5). However, the NTSB believes that the safety information communicated by a pilot (either verbally, via ACARS, or by some other means) in a PIREP should be not held as private information and is concerned that these types of proprietary practices unnecessarily inhibit the dissemination of flight safety information.

Some operators recognize the value in sharing PIREP information and have gone to great effort to do so. United Airlines, for example, was a pioneer in developing an innovative solution for sending its PIREPs (which previously could not be extracted from its legacy computer systems) to the NWS for dissemination. According to United's flight dispatch services senior manager, after a company aircraft was involved in a severe turbulence encounter in December 1997 that resulted in the death of 1 passenger and injuries to 74 others, the airline began to research how to share PIREPs both within and outside the company to help with tactical weather hazard avoidance. The airline developed its own computer processor and interface to collect and disseminate PIREPs, which it has been using for years. Dispatchers who receive a PIREP from a flight crew not only can send the information to other company aircraft that may be affected but also can use the interface to input the report for formatting and transmittal to the NWS (NTSB 2016a, 104-105).

Although Southwest Airlines uses a private weather vendor service, its dispatchers are responsible for sharing PIREPs to the NAS. According to Southwest's senior manager of dispatch training, the airline's manuals use command language for pilots and dispatchers regarding PIREPs, such as "will communicate" and "must send"; he described it as a mandate for pilots and dispatchers to assist in the safe operation of both company flights and other flights in the NAS (NTSB 2016a, 110). Southwest's senior manager of dispatch training stated that the pilots submit most of their PIREPs to dispatchers via ACARS; dispatchers then send the information to other company aircraft that may be affected and type the PIREP into the AWC online PIREP-submission form (discussed in the next section) to share it to the NAS.

The FAA also has recognized the importance of widely sharing PIREPs in the interest of flight safety. In an effort to prevent injuries caused by turbulence, the FAA issued AC 120-88A, "Preventing Injuries Caused by Turbulence," which suggested several measures to air carriers, one of which was to establish PIREP awareness campaigns, training, and communication links to encourage flight crews to deliver company PIREPs to the NAS (FAA 2006). The NTSB agrees

[60] Private weather service providers are commercial entities that use their data, modeling, weather product packaging, and equipment to provide their unique products and services to subscribing customers.

with this philosophy and its potential to enhance safety using all types of PIREPs. The NTSB concludes that unrestricted sharing of PIREP information, without exception to operator or weather service provider, should be encouraged as a standard operating procedure for all operators to improve flight safety and runway surface safety in the NAS. Therefore, the NTSB recommends that the FAA encourage industry safety efforts, such as the Commercial Aviation Safety Team and the GAJSC, to identify, develop, and implement incentives for 14 *CFR* Part 121, 135, and 91K operators and the GA community to freely share PIREPs, including braking action or runway condition reports filed as PIREPs, to the NAS to enhance flight safety.

3.2.2 Need for Reliable Direct Submission Capability

Operators that are committed to sharing PIREPs currently have limited options for submitting PIREPs for public distribution. In a September 2012 newsletter, the FAA reported its expectation that WMSCR would be able to capture and make PIREPs available to the NAS via the System Wide Information Management (SWIM) information-sharing platform (FAA 2012). The FAA anticipated that this capability could significantly enhance NAS safety and would greatly increase the scope of coverage of PIREPs. As of the date of this report, the capability is still in the developmental stages; however, in follow-up correspondence regarding a February 2017 target date referenced at the NTSB's June 2016 forum (NTSB 2016a, 179), a representative from the SWIM program office reported that the office was targeting April 2017 for the "submit PIREPs" capability. The FAA considers SWIM "the digital data-sharing backbone of NextGen."[61]

In August 2014, the FAA issued Information for Operators (InFO) 14011, "Electronic Submission of Pilot Weather Reports," (FAA 2014d) in an effort to increase operators' abilities to submit PIREP information directly for rapid, nationwide distribution. InFO 14011 requested that operators submit PIREPs directly to the AWC website via an online submission tool.[62] The AWC described the online submission form as supplemental to the FAA's AIS-R system and noted that PIREPs submitted via the website would be formatted, distributed, and displayed graphically for NAS users.

The AWC maintains user authentication and quality control procedures to prevent unauthorized access to the website or the submission of faulty data; however, an unexpected influx of new user authentication requests (after the issuance of FAA InFO 14011) temporarily overwhelmed the website's capabilities. Although the website's existing 78 authorized users (which included some Part 121 operators, Part 135 operators, and CWSUs) were able to continue inputting PIREP data using the website, new user account creation was suspended until software and hardware upgrades could be completed. On April 12, 2016, the AWC resumed new user registrations and again made available the online PIREP-submission form for pilots, operators, and others to use on "an experimental basis to solicit feedback." Between April and June 2016, about 250 additional users from the GA community signed up to use the submission form;

[61] For more information, see the FAA's SWIM web page, which can be accessed from its NextGen web page (www.faa.gov/nextgen).

[62] FAA InFO 14011's suggestions addressed "Part 121 Domestic/Flag Dispatchers, Part 121 Supplemental personnel authorized to exercise operational control, Part 91K Program Managers with an Operations Center, [14 *CFR*] 135.619 HEMS [helicopter emergency medical services] Operation Control Centers with 10 or more Helicopter Air Ambulances, and [GA] users."

however, about mid-June 2016, the AWC experienced a security breach and had to again take the form offline, with the intent to have it operational in the near future (NTSB 2016a, 39, 90).

The recent service interruptions with the AWC web tool and the current lack of widespread access to NextGen's SWIM/WMSCR services illustrate that operators have limited options for submitting PIREPs for public distribution. The NTSB concludes that an effective automated PIREP-submission and data-collection tool, reliably available and capable of accepting data from all pilots, operators, and other users who meet the registration criteria and want to participate, would improve the quantity of PIREPs available to support flight safety for all users in the NAS. Therefore, the NTSB recommends that the FAA provide a reliable means of electronically accepting PIREPs directly from all users who are eligible to submit reports, and ensure that the system has the capacity to accept and make available all such reports to the NAS.

4. Additional Data Needed by Aviation Meteorologists

As described throughout this report, PIREPs are critical sources of information supporting meteorologists' development of hazardous weather advisories and forecasts. In some cases, when meteorologists are watching certain weather patterns or expecting hazardous weather phenomena to develop, they may communicate the need for PIREPs to the ATC facility that has authority over that area; for example, a CWSU may notify local facilities that it could use more reports in a certain area at a certain time (NTSB 2016a, 71).

4.1 Need for More Overnight Reports

At the NTSB's June 2016 forum, the AWC warning coordination meteorologist stated that weather personnel receive very few, if any, PIREPs during overnight hours (NTSB 2016a, 39), which affects the accuracy of forecasts and advisory products during that period. For example, the accuracy of the analysis for the GTG product, which provides a three-dimensional diagnosis and forecast of the location and intensity of potential clear air turbulence, is adversely affected by the fewer number of overnight PIREPs received (FAA 2014a).

The Cargo Airline Association (CAA), an industry group that represents the all-cargo air carrier industry, has a membership that includes some of the country's largest cargo air carrier operators, which conduct overnight operations.[63] As such, the NTSB believes that the CAA is in a unique position to help increase the voluntary submission of PIREPs from its members, particularly in the overnight hours. The NTSB concludes that the current volume of PIREPs received during the overnight hours is insufficient to optimally support the NWS's efforts to develop accurate weather products and advisories to support flight safety in the NAS. Therefore, the NTSB recommends that CAA encourage its members to provide more PIREPs during overnight flight hours, either by increased reporting by flight crews or by increased solicitation by dispatch or other personnel, and ensure that those PIREPs are submitted for dissemination to the NAS.

4.2 Value of Older and Archived Data

Currently, FAA contract limitations do not allow PIREPs that are older than 1 hour to be submitted to the NAS. Although PIREPs older than 1 hour have little value for flight planning and air traffic tactical or weather advisory uses, the AWC warning coordination meteorologist stated that PIREPs that are up to 2 or 3 hours old are beneficial for use in day-to-day weather forecasting (NTSB 2016a, 36). According to Aerovie's founder, with the current 1-hour limitation, over the past 2 years, 88% of PIREPs submitted using the application were accepted into the NAS. He noted that, if the window were expanded to 5 hours, the acceptance rate would have been 97%

[63] CAA's air carrier members are ABX Air, Inc.; Atlas Air Worldwide; FedEx Express; United Parcel Service; DHL Express; and Kalitta Air, LLC; its associate members are Alaska International Airport System, Amazon, Campbell-Hill Aviation Group, Louisville International Airport, Memphis-Shelby County Airport Authority, Ft. Wayne International Airport, and Spokane International Airport.

(NTSB 2016b, 104). The NTSB concludes that expanding the acceptance window for PIREPs would enable more data to be captured for meteorological uses, particularly from those pilots who choose to submit PIREPs after landing or who use applications or web-based tools that have connectivity limitations.

The NTSB notes that PIREP display user interfaces (such as the AWC's ADDS web page, which displays PIREPs in either text or graphical format, and briefing package interfaces used by some airlines) enable users to filter the age of the PIREPs they wish to see (the ADDS page allows selections between 1 and 36 hours). As a result, accepting older reports into the database should not adversely affect users who do not want to see them. Therefore, the NTSB recommends that the FAA remove the 1-hour age limitation for accepting PIREPs.

At the NTSB's June 2016 forum, meteorologists, an NCAR associate scientist, and an airline operations safety representative all expressed a desire to have an "infinite retention" of archived PIREPs. Archived data are an important part of the climate record. One NWS meteorologist said that PIREPs are "probably the one observational dataset that's the most difficult to find" and that an archive of PIREPs would be helpful for the validation of forecasts and for performing case studies, which are used to help improve forecasting of turbulence, icing, and other aviation hazards. A CWSU meteorologist stated that, just as surface data are retained, it would be helpful to similarly retain upper atmosphere data, like that reported in PIREPs. As discussed in section 2, PIREPs provide information that improves automated products such as the GTG, the CIP, and the FIP. The FAA's Aviation Weather Research Program sponsors research initiatives behind such forecast products. From an airline perspective, safety personnel use the data for safety investigations and for making program corrections (NTSB 2016a, 201-204).

A WMSCR program representative stated that although data storage for archived PIREPs is not an issue, current technology does not support retrieving the data in a standard way. He stated that SWIM is the solution because the migration of PIREPs and other weather products into exchange models will provide the ability to store metadata along with the PIREPs that will allow them to be retrieved based on criteria (such as a location reference). However, the exchange model transfer itself will require storing a large amount of information that must be maintained (NTSB 2016b, 179). The NTSB concludes that archived PIREPs are an important source of climate data for use in improving the forecasting of turbulence, icing, and other aviation hazards. Therefore, the NTSB recommends that the FAA maintain a database of PIREPs that archives the data for at least 1 year and that provides search and retrieval capabilities to support meteorological, research, and other uses.

4.3 Previously Issued Safety Recommendation

In 2014, the NTSB identified inconsistencies in how the AWC, CWSU, and NWS use PIREPs in deciding when to issue advisories. These inconsistencies were highlighted in two accident investigations: one was the previously referenced March 2012 Learjet 35A incident, and the other involved a Socata TBM 700 airplane that encountered unforecasted severe icing conditions in Morristown, New Jersey, in December 2011. The issues discovered during these investigations prompted the NTSB to issue Safety Recommendation A-14-21 on May 6, 2014, to recommend that the NWS "[e]stablish standardized guidance for all…[NWS] aviation weather forecasters on the weighting of information reported in…PIREPs that will (1) promote consistent determination of hazard severity reported in a PIREP, and (2) assist in aviation weather product issuance."

On July 29, 2014, the NWS responded that it was assessing standardized weighting of information reported in PIREPs to promote consistent determination of hazard severity and assist in aviation weather product issuance. It stated that it would update policy instructions, as needed, to incorporate standardized guidance on weighting of information from PIREPs and would inform the FAA of the changes to NWS policy guidance. As a result, pending completion of the work, the NTSB classified Safety Recommendation A-14-21 "Open—Acceptable Response" on September 26, 2014.[64]

[64] For more information, see Safety Recommendation A-14-21.

5. Role of Technology for Future of PIREPs and Automated Aircraft-Based Observations

NextGen and other technology that will expand the safety benefits of PIREP information in the NAS is rapidly evolving. At the NTSB's June 2016 forum, the LMFS chief architect indicated that LMFS personnel now have a lower workload demand for traditional telephone and radio in-flight services and instead provide more services through automation and the online web services infrastructure. Other LMFS capabilities (for use with partnering application or avionics companies) include the ability to monitor flight plans and provide an alerting service by which LMFS pushes weather information to a pilot if it appears that it will affect the pilot's filed route of flight. These alerts can be delivered via e-mail, text, and satellite communication devices and include disseminating PIREPs electronically to other pilots based on their flight plans (NTSB 2016a, 127-128, 196).

LMFS is also working with prototypes for automating PIREP solicitation that could include determining whether there is an area from which more PIREP information is needed, such as an AIRMET area that may need to be refined, and then sending a PIREP query to pilots of equipped aircraft in that area (NTSB 2016a, 126). Aerovie is also exploring features that could someday enable a pilot to highlight an area of interest on a map and ask other users in the system to submit a PIREP for that area (NTSB 2016b, 105).

Although current use of the electronic submission of PIREPs to LMFS is relatively modest (as discussed in section 2.1.3), the LMFS chief architect described potential future improvements that may occur as communications capabilities in GA aircraft increase. Textual PIREP transmissions from an aircraft via datalink, now accomplished primarily in transport-category aircraft via ACARS, may someday be widespread across GA, as datalink equipment installations increase and capabilities evolve. Currently, four companies use the Iridium satellite constellation to establish a datalink with LMFS, and, according to the LMFS chief architect, the bidirectional communication enables a wide variety of safety-oriented communication, including soliciting, submitting, and disseminating PIREPs.

Although some of the current required equipment and service plans needed for satellite communications may be cost prohibitive for smaller GA users (current platforms include the business jet market), costs could decrease as more capabilities evolve. The LMFS chief architect described that it may someday be possible to work with communications providers (such as Iridium and the FAA) to find ways to lower the costs of communicating safety-related aviation data (NTSB 2016a, 123, 129).

According to 14 *CFR* 91.225 and 91.227, effective January 1, 2020, all aircraft operating in airspace defined in the regulation are required to have an automatic dependent surveillance-broadcast (ADS-B) system, which is a foundational NextGen technology. ADS-B can currently uplink weather information, including next-generation radar data and PIREPs, to more than 15,700 aircraft that are equipped to take advantage of the ADS-B In service (NTSB 2016b, 228). A senior safety advisor for the AOPA Air Safety Institute questioned whether future advances in capabilities with the universal access transceiver (UAT) datalink channel on ADS-B might someday enable a breakthrough on how PIREPs are submitted by pilots of GA aircraft (Landsberg 2016). According to the LMFS chief architect, initial inquiries into using the ADS-B infrastructure as a communications mechanism revealed "tremendous obstacles" to making that happen in a timely manner (NTSB 2016a, 123).

Regarding the potential for such capabilities, a senior systems engineer familiar with the program described that the next version of the minimum operational standards (MOPS) is planned for the 2018 to 2019 timeframe; the FAA would then need to create the technical standard order in accordance with the MOPS, and industry would need to take that information and design, build, and certify the equipment. He estimated that it would probably be the 2023 to 2025 timeframe before such equipment could be available (NTSB 2016b, 166).

As ADS-B and other technologies continue to evolve for GA applications, current capabilities for larger (primarily transport-category) aircraft show how connectivity and other automation, particularly through onboard sensors and other aircraft equipment, can collect and provide data that can improve weather information and forecast products. Automated aircraft-based observations (ABOs) remove human involvement by using onboard equipment to accurately capture observation time, location, and a variety of sensor-derived parameters, such as wind information, aircraft accelerations, and temperature (and, in some cases, humidity/water vapor information) and transmit the data in near real time via ACARS.

Depending on equipment type, different aircraft can provide a variety of aircraft meteorological data reports (AMDAR). According to the NWS ABO program manager, the AMDAR program is supported worldwide by more than 3,000 aircraft from 38 to 40 airlines, which contribute more than 650,000 high-quality ABOs per day. These include 60,000 profiles per week of ascent and descent data over the continental United States. These data have resulted in an up to 30% increase in accuracy of some numerical weather prediction models (NTSB 2016b, 108-110). The AMDAR program includes different contracts with participating airlines, the FAA, and the NWS; however, a subset of the ABO data (data collected from aircraft operated under Part 135) is publicly available in real time through NOAA's meteorological assimilation data ingest system (MADIS). Other publicly available ABO data include aircraft reports (AIREPs), which are human-initiated, semi-automated ABOs that are displayed both graphically and in text format on the AWC website.[65]

According to a research meteorologist with the FAA's NextGen Aviation Weather Division who is also the lead for the Aviation Weather Research Program's turbulence project, turbulence is not only a safety concern but also a NAS capacity concern: reroutes and diversions due to turbulence or anticipated turbulence degrade NAS capacity, and crew-initiated altitude deviation to avoid turbulence results in a significant waste of fuel (NTSB 2016b, 113-114). Although human observations of turbulence reported in PIREPs can be both subjective and aircraft dependent (what is perceived to be light turbulence for a transport-category aircraft may produce moderate or severe effects for a GA aircraft), sensor-derived measurements are objective. Currently in the United States, about 190 aircraft (from three airlines) participate in the FAA-sponsored

[65] AIREPs contain information derived from sensors on the aircraft and may also contain information from the pilot's observation. AIREPs are automatically disseminated to the World Meteorological Organization.

NCAR program and provide more than 11,700 measurements per day.[66] These data are used in the development of turbulence-avoidance tools. Currently, these data are propriety to the participating airlines; however, the turbulence project research meteorologist noted that efforts are underway to process and store these data on NWS system, and the NWS will control access (NTSB 2016b, 120-121). In 2013, the FAA informed the NTSB that it has the meteorological data-collection and -reporting system (operated by the FAA and the NWS in collaboration with the participating commercial airlines) that provides airborne weather observations of winds and temperature (and, in some cases, water vapor) to NWS forecast models and personnel.[67]

Private commercial entities, including The Weather Company (proprietors of the turbulence auto PIREP system [TAPS]) and Panasonic Avionics Corporations (proprietors of the tropospheric airborne meteorological data reporting [TAMDAR] system) have developed programs that retrieve atmospheric data, including turbulence and/or icing information, from sensor-equipped airborne aircraft to create their own unique weather information products, forecasts, and alerts for the benefit of the participating airlines that invest in the equipment and services (NTSB 2016b, 121-135). Although data collected by private vendors are not publicly available to the NAS, the programs illustrate the types of solutions that technology and automation can provide for collecting and communicating large volumes of accurate data. Just as communication technologies continue to evolve toward a more practical and affordable capability to transmit data from smaller aircraft, aircraft sensor and/or other automated data-collection capabilities will likely evolve for smaller aircraft installations, particularly for technically advanced aircraft.

While automated technologies show tremendous potential, human observations will always provide a much-needed source of in situ weather information for improving safety in the NAS. For human observations to be most effective, all PIREP user groups must be informed, trained, and motivated to put forth their best efforts at increasing the quantity, improving the quality, and expediting the dissemination of such reports. The NTSB believes that the actions recommended in this report not only will improve safety within the constraints of the current system but also will provide a solid foundation to take best advantage of emerging technologies to put more and better weather information in front of the users who need it most when they need it most. These will include ADS-B and other NextGen capabilities, like those possible through ERAM and SWIM, which provide the foundational infrastructure and data-sharing platforms for automating ATC functions and other communications and functions in the NAS. The NTSB concludes that technological improvements that can automatically capture aircraft location, time, aircraft type,

[66] NCAR developed a turbulence detection algorithm, eddy dissipation rate (EDR), which is an aircraft-independent measure of the turbulent state of the atmosphere. EDR is calculated from measurements taken by sensors, such as wind and accelerometer readings, onboard the aircraft. Although NCAR developed one EDR algorithm as part of the FAA-funded program, other entities have developed their own algorithms.

[67] The FAA provided this information in its response to NTSB Safety Recommendations A-11-50 and -51, which asked the FAA to implement a collaborative test program in Alaska to establish the viability of relaying weather information collected from aircraft equipped with existing datalink technology, such as UATs, to the NWS AAWU in real time and encourage and provide incentives to datalink-equipped aircraft operators in Alaska to outfit their aircraft with weather-sensing equipment for real-time data relay. The FAA stated that, although it concurred with the recommendations, it was exploring with the NWS more cost-effective ways to achieve a similar safety objective. At the time of the response, the FAA noted that, although downlink capabilities were well developed and in use for more than 20 years, GA aircraft were not generally equipped with sensors that could reliably collect weather information, and the standards for such sensors had not yet been developed. Safety Recommendations A-11-50 and -51 were classified "Closed—Unacceptable Action" on July 8, 2013.

and other information to reduce workload and distraction for pilots, air traffic controllers, and others who handle PIREPs are an essential part of the long-term solution for increasing PIREP submissions, reducing errors, and expediting their distribution to the NAS.

6. Conclusions

1. Education that fosters pilot understanding of the importance and uses of all pilot weather reports (PIREPs), weather-assessment and -reporting skills, and familiarity with the PIREP format can increase the likelihood that pilots will file PIREPs.

2. Pilots who learn how to file pilot weather reports (PIREPs) during initial flight training and who practice the skill during recurrent training and flight reviews are more likely to routinely submit PIREPs.

3. The process by which flight service station specialists receive and verify verbal pilot weather report (PIREP) information is having an unintended deterrent effect on reporting because some pilots find the process too time consuming and, therefore, choose not to submit PIREPs.

4. Educating pilots about the safety benefits of hazardous-weather pilot weather reports (PIREPs), Federal Aviation Administration enforcement policies related to PIREPs, and the potential protections of the National Aeronautics and Space Administration-administered aviation safety reporting system may encourage more pilots to file a PIREP in the event of an inadvertent encounter with hazardous weather.

5. A single source of standardized guidance for pilot weather report (PIREP) reporting and coding, as well as weather assessment and classification criteria for low-level windshear, turbulence, and fair weather, can help reduce omissions and subjectivity errors in PIREPs.

6. Defining the criteria for reporting the unique characteristics of mountain waves and for classifying their intensity in pilot weather reports (PIREPs) and educating pilots on these criteria and classifications will increase the usefulness of the PIREPs for a variety of safety functions in the National Airspace System, including tactical hazardous weather avoidance and the development of forecasts and weather advisory products.

7. Air traffic control facilities that consistently solicit and disseminate a high volume of quality pilot weather reports (PIREPs) have developed internal monitoring processes, self-evaluation criteria, leadership and cultural change initiatives, and/or procedural solutions that like facilities can learn from and adopt—or adapt—to improve PIREP-handling performance.

8. Established user-interface design practices for automated systems for entering coded information, such as those that the Federal Aviation Administration applied to improve the collection and dissemination of its digital notice-to-airmen data through a common exchange model, could produce similar improvements in the process by which air traffic controllers collect and disseminate pilot weather report data.

9. Inconsistent and ambiguous information contained in various pilot weather report (PIREP) guidance and procedures documents for air traffic controllers can lead to confusion and possible errors in PIREP solicitation, documentation, and dissemination.

10. Scenario-based education for air traffic controllers that uses real-world examples can help controllers better understand the importance and uses of all pilot weather reports (PIREPs), which may foster a safety culture that motivates controllers to reduce PIREP-handling omissions and errors.

11. Unrestricted sharing of pilot weather report information, without exception to operator or weather service provider, should be encouraged as a standard operating procedure for all operators to improve flight safety and runway surface safety in the National Airspace System.

12. An effective automated pilot weather report (PIREP)-submission and data-collection tool, reliably available and capable of accepting data from all pilots, operators, and other users who meet the registration criteria and want to participate, would improve the quantity of PIREPs available to support flight safety for all users in the National Airspace System.

13. The current volume of pilot weather reports received during the overnight hours is insufficient to optimally support the National Weather Service’s efforts to develop accurate weather products and advisories to support flight safety in the National Airspace System.

14. Expanding the acceptance window for pilot weather reports (PIREPs) would enable more data to be captured for meteorological uses, particularly from those pilots who choose to submit PIREPs after landing or who use applications or web-based tools that have connectivity limitations.

15. Archived pilot weather reports are an important source of climate data for use in improving the forecasting of turbulence, icing, and other aviation hazards.

16. Technological improvements that can automatically capture aircraft location, time, aircraft type, and other information to reduce workload and distraction for pilots, air traffic controllers, and others who handle pilot weather reports (PIREPs) are an essential part of the long-term solution for increasing PIREP submissions, reducing errors, and expediting their distribution to the National Airspace System.

7. Recommendations

To the Aircraft Owners and Pilots Association Air Safety Institute:

Update your online pilot weather report (PIREP) course content to include, at a minimum, scenario-based training that uses real-world examples that (1) illustrate the value of both fair-weather and adverse-weather PIREPs, (2) explain how meteorologists use PIREPs to verify and revise aviation weather forecasts and advisory products to improve safety in the National Airspace System, (3) provide guidance on how to assess and describe weather phenomena and report their location accurately, and (4) demonstrate the various ways to submit PIREPs. (A-17-14)

To the Aviation Accreditation Board International, the National Association of Flight Instructors, and the Society of Aviation and Flight Educators (each, respectively):

Encourage your members to teach their students, during initial flight training, recurrent flight training, and flight reviews, the importance of pilot weather reports (PIREPs) and include, at a minimum, (1) real-world examples that illustrate the value of both fair-weather and adverse-weather PIREPs; (2) explanations of how PIREPs are used by and benefit various users in the National Airspace System; (3) examples of the various ways to submit PIREPs while minimizing distraction; and (4) practical experience assessing weather and submitting a PIREP of the observed phenomena, including reporting their location accurately. (A-17-15)

To the Federal Aviation Administration:

Review the process by which federal and contract flight service station specialists receive verbal pilot weather reports and then simplify procedures to reduce the amount of time the specialists take to obtain the necessary information from pilots. (A-17-16)

Develop and distribute information that emphasizes the safety importance of hazardous-weather pilot weather reports (PIREPs) and explains examples of regulatory violations in which the Federal Aviation Administration may use PIREPs in enforcement action, as well as the potential protection from sanction under the aviation safety reporting system. (A-17-17)

In collaboration with the National Weather Service, (1) revise and harmonize the pilot weather report (PIREP) guidance in the *Aeronautical Information Manual* (AIM) and Advisory Circular (AC) 00-45H, including but not limited to the guidance and criteria for reporting low-level windshear (to specify airspeed gain or loss), turbulence (to specify in-cloud or out-of-cloud), and fair weather; and (2) revise the AIM to either include comprehensive PIREP-coding guidance or to clearly reference AC 00-45H as the source of this information. (A-17-18)

In collaboration with the National Weather Service, revise the *Aeronautical Information Manual* and Advisory Circular 00-45H to define standard criteria for reporting mountain wave activity in pilot weather reports (PIREPs) that include (1) consideration that not all hazardous mountain wave encounters involve turbulence; (2) airspeed fluctuation range, altitude fluctuation range, and any other information needed to adequately describe the effects of the mountain wave activity on the aircraft; (3) parameters for classifying the intensity level of the conditions for a turbulent wave encounter and a smooth wave encounter; and (4) the threshold at which the PIREP for each type of encounter (turbulent or smooth) should be coded as urgent. (A-17-19)

In collaboration with the National Air Traffic Controllers Association, develop and distribute to all air traffic control (ATC) facilities best practices guidance for the solicitation and dissemination of pilot weather reports for each type of ATC facility. (A-17-20)

Provide air traffic controllers with automated pilot weather report (PIREP) data-collection tools that incorporate design elements to prevent input errors, increase quantity, and improve the timeliness of PIREPs disseminated to the National Airspace System. (A-17-21)

Incorporate automation technology that captures data elements from air traffic controllers' displays, including aircraft type, time, location, and altitude, to automatically populate these data into a pilot weather report (PIREP)-collection and -dissemination tool that will enable controllers to enter the remaining PIREP elements and disseminate PIREPs through a common exchange model directly to the National Airspace System. (A-17-22)

Revise Federal Aviation Administration Orders JO 7110.65W, "Air Traffic Control"; JO 7110.10Y, "Flight Services"; and JO 7210.3Z, "Facility Operation and Administration," to ensure that the chapters of the orders that address pilot weather reports (PIREPs) include improved and consistent guidance about PIREP coding, handling, solicitation, and dissemination. (A-17-23)

Review and revise air traffic controller training to ensure that it provides scenario-based education, relevant to the controller's specific facility type and location, that includes real-world examples that demonstrate the value of both fair-weather and adverse-weather pilot weather reports (PIREPs) to weather forecasters and that shows how location inaccuracies and common collection and dissemination errors, including the consolidation of multiple PIREPs, adversely affect the usefulness of the reports to all National Airspace System users. (A-17-24)

Encourage industry safety efforts, such as the Commercial Aviation Safety Team and the General Aviation Joint Steering Committee, to identify, develop, and implement incentives for 14 *Code of Federal Regulations* Part 121, 135, and 91K operators and the general aviation community to freely share pilot weather reports (PIREPs), including braking action or runway condition reports filed as PIREPs, to the National Airspace System to enhance flight safety. (A-17-25)

Provide a reliable means of electronically accepting pilot weather reports directly from all users who are eligible to submit reports, and ensure that the system has the capacity to accept and make available all such reports to the National Airspace System. (A-17-26)

Remove the 1-hour age limitation for accepting pilot weather reports. (A-17-27)

Maintain a database of pilot weather reports that archives the data for at least 1 year and that provides search and retrieval capabilities to support meteorological, research, and other uses. (A-17-28)

To the National Weather Service:

Work with the Federal Aviation Administration to (1) revise and harmonize the pilot weather report (PIREP) guidance in the *Aeronautical Information Manual* (AIM) and Advisory Circular (AC) 00-45H, including but not limited to the guidance and criteria for reporting low-level windshear (to specify airspeed gain or loss), turbulence (to specify in-cloud or out-of-cloud), and fair weather; and (2) revise the AIM to either include comprehensive PIREP-coding guidance or to clearly reference AC 00-45H as the source of this information. (A-17-29)

Work with the Federal Aviation Administration to revise the *Aeronautical Information Manual* and Advisory Circular 00-45H to define standard criteria for reporting mountain wave activity in pilot weather reports (PIREPs) that include (1) consideration that not all hazardous mountain wave encounters involve turbulence; (2) airspeed fluctuation range, altitude fluctuation range, and any other information needed to adequately describe the effects of the mountain wave activity on the aircraft; (3) parameters for classifying the intensity level of the conditions for a turbulent wave encounter and a smooth wave encounter; and (4) the threshold at which the PIREP for each type of encounter (turbulent or smooth) should be coded as urgent. (A-17-30)

To the National Air Traffic Controllers Association:

Work with the Federal Aviation Administration to develop and distribute to all air traffic control (ATC) facilities best practices guidance for the solicitation and dissemination of pilot weather reports for each type of ATC facility. (A-17-31)

To the Cargo Airline Association:

Encourage your members to provide more pilot weather reports (PIREPs) during overnight flight hours, either by increased reporting by flight crews or by increased solicitation by dispatch or other personnel, and ensure that those PIREPs are submitted for dissemination to the National Airspace System. (A-17-32)

BY THE NATIONAL TRANSPORTATION SAFETY BOARD

T. BELLA DINH-ZARR
Acting Chairman

CHRISTOPHER A. HART
Member

ROBERT L. SUMWALT, III
Member

EARL F. WEENER
Member

Adopted: March 29, 2017

8. Appendix A

Supporting Information for Section 1

PIREP Pathways to the NAS

Although the procedures and data systems for processing submitted PIREPs vary, the FAA's WMSCR system database ultimately collects and makes available the PIREP information for access by NAS users. Figure A-1 shows some of the possible paths a PIREP may take before it becomes publicly available via WMSCR to the NAS.

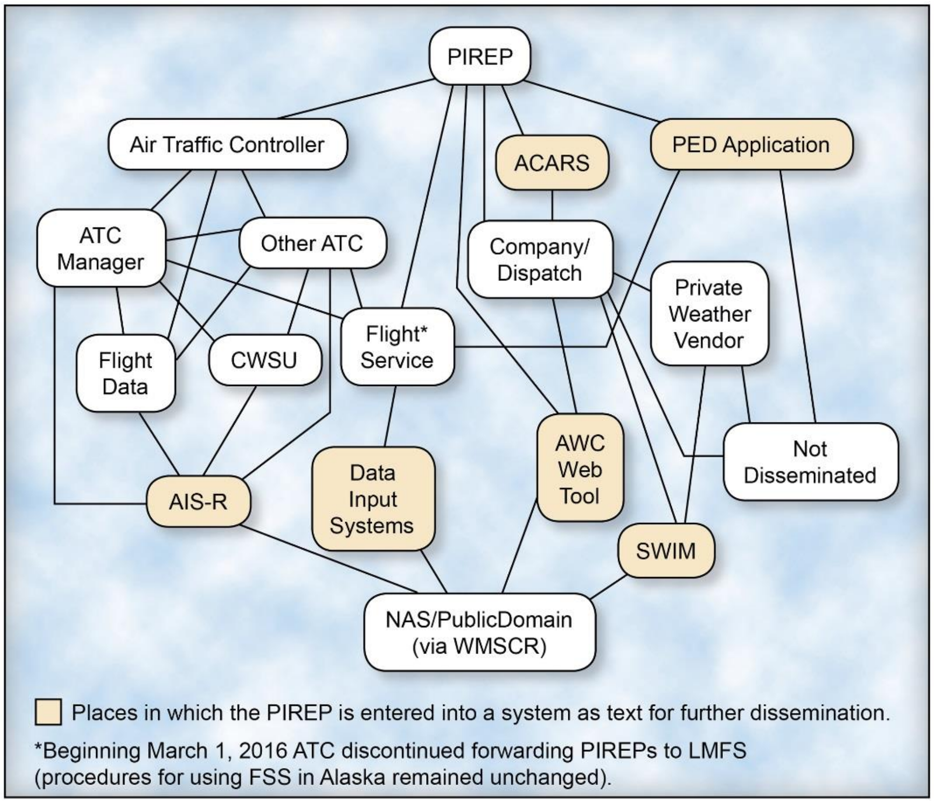

Figure A-1. Diagram showing some of the possible paths a PIREP may take before it is publicly available to the NAS.

(Return to section 1 of the report.)

Supporting Information for Section 2

Examples of Weather Product Uses

Forecasters have noted that even a single PIREP can influence the decision to issue (or discontinue) a hazardous weather advisory or amend its geographic area (see figure A-2).

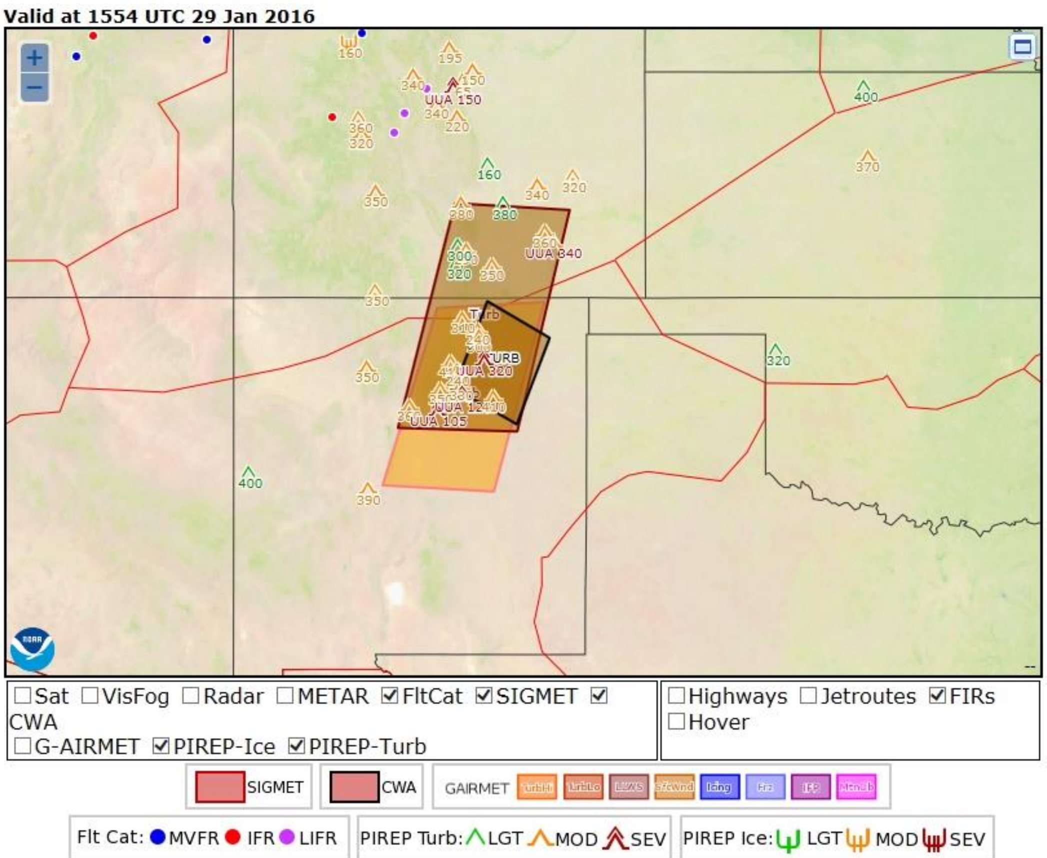

Figure A-2. Map showing where hazardous weather advisories and PIREPs of moderate-to-severe turbulence coincide.

In one example, an AWC forecaster described to NTSB staff a scenario in which, while talking to an air traffic controller at the Salt Lake City ARTCC, he learned that the facility received three PIREPs of mountain wave activity with moderate-to-severe conditions; however, the forecaster saw only one such PIREP in the public system. Although the AWC forecaster likely found it beneficial to be aware of the other two PIREPs, the forecaster would need all of the information from the missing PIREPs to be able to plot them on a map to verify that aviation warnings and advisory products are tailored to cover the correct areas. AIRMETs and SIGMETs, which are issued by the AWC, are used in conjunction with area forecasts to advise of weather hazards, including IMC, icing, or turbulence. For use in assessing the quality of weather forecasts and improving graphical weather products, PIREPs that describe favorable weather conditions (including "negative" reports indicating a lack of turbulence or icing) or conditions that are as forecasted are just as important as reports of adverse weather or conditions that are different than forecasted.

During the NTSB's investigation of a fatal accident involving a Cessna 208B in November 2013 in St. Mary's, Alaska, one weather forecaster reported that surface observations, PIREPs, and model data are the most important tools for weather forecasting and that more PIREPs are needed. Like many forecasters, this forecaster routinely compared computer models to see how they matched up with available PIREPs, and he noted that PIREPs are needed to verify where icing is occurring.[68]

PIREPs can provide atmospheric data that can improve the accuracy of NWS global forecast models and add value to current icing and turbulence prediction algorithms. For example, the CIP combines PIREPs with data collected from satellite, surface, radar, and lightning observations and model output to provide a detailed assessment of the potential for icing and supercooled large droplets (Bernstein et al. 2005). One study noted that PIREPs of icing location and intensity provide valuable information used by the CIP. According to the study, PIREPs, which are the only actual in situ observations of icing severity on an aircraft, are useful when combined with other data to diagnose icing severity at a given location (Wolff et al. 2007).

(Return to section 2 of the report.)

Current Limitations of Electronic Submission Tools

According to AOPA's 2016 survey, only 38 of about 700 pilots who responded used technology other than the radio to file PIREPs (NTSB 2016b, 24). The LMFS chief architect also noted that the current use of tools to electronically submit PIREPs to LMFS remains modest; between January to mid-June 2016, only about 500 total PIREPs (20 to 25 of which were coded as urgent) were submitted electronically (NTSB 2016a, 128-129). He stated that 20 companies' platforms are currently operational with LMFS, and 15 more are in progress (NTSB 2016a, 121). Aerovie's founder also noted that many of the electronic flight bag's 5,000 users have never used its PIREP-submission feature (NTSB 2016b, 101). According to the LMFS chief architect, a possible reason for the relatively low submission numbers, in addition to a lack of pilot awareness of the LMFS service, may be the current limitations on communications capability (NTSB 2016a, 128-129). For example, many applications and web-based PIREP-submission tools rely on Internet connectivity to transmit data; therefore, PIREP information input during flight (assuming the aircraft does not have connectivity via Iridium satellite) would be queued until network connections are available, typically after landing, when a cellular or WiFi signal can be accessed.[69] During longer flights, this delay would prevent ATC, FSS, and other NAS users from receiving the information in a timely manner, if at all. Aerovie's founder stated that, due to FAA contract limitations with LMFS, queued PIREPs more than 1-hour old are dropped and not submitted to the NAS.

According to Aerovie's founder, an important consideration for using electronic PIREP-submission applications or web-based tools in the cockpit is that their use requires some

[68] The NTSB determined that the accident was caused, in part, by the pilot's decision to initiate a visual flight rules approach into an area of IMC at night. For more information about this accident, see NTSB case number ANC14MA008.

[69] Four companies currently accomplish datalink communications with LMFS using the Iridium satellite constellation (NTSB 2016a, 123). Some connectivity and service options may improve in the future as capabilities evolve; these possibilities are discussed further in section 5 of this report.

limited head-down time; he noted that "distractions cannot be underestimated" (NTSB 2016b, 104). The NTSB notes that, because the application requires such interaction, there are some circumstances in which safe in-flight use may be impractical or imprudent. Although Aerovie enables a pilot to enter historical PIREP information after landing (the pilot can input the time that observation actually occurred and select the location on a map), Aerovie's founder stated that some PIREPs, like those reporting severe conditions or icing, should be delivered directly to ATC via the radio (NTSB 2016b, 104). As mentioned in section 2.1.2, this would enable controllers, other pilots, dispatchers, and others to immediately become aware of the information for tactical safety use.

(Return to section 2.1.3 of the report.)

9. Appendix B

Recent NTSB Investigations

Date	NTSB Case No.	Aircraft	Severity and Number of Injuries	14 *CFR* Part	PIREP Concern Category†
3/5/2012	ANC12IA024	Learjet 35A	None (6)	135	Dissemination (controller)
6/7/2012	CEN12LA345	Learjet 60	None (8)	91	Dissemination (controller)
8/11/2012	ERA12LA500	Beech V35B	None (2)	91	Solicitation (controller)
12/18/2012	WPR13FA072	Piper PA-31-350	Fatal (1)	135	Dissemination (controller)
10/18/2013	CEN14FA009	Cessna 500	Fatal (2)	91	Dissemination (controller)
11/29/2013	ANC14MA008	Cessna 208B	Fatal (4) Serious (6)	135	Dissemination (operator)
12/8/2013	ERA14FA068	Cessna 310R	Fatal (3)	91	Dissemination (controller)
2/3/2014	ERA14FA112	Commander 690	Fatal (4)	91	Dissemination (controller)
4/11/2014	ERA14FA192	Piper PA-32RT-300T	Fatal (2)	91	Solicitation, dissemination (controller)
2/5/2015	CEN15LA137	Beech A36	Serious (2) Minor (2)	91	Solicitation, dissemination, prioritization (controller)
4/7/2015	CEN15FA190	Cessna 414A	Fatal (7)	91	Solicitation (controller)*
6/10/2015	DCA15CA131	Bombardier CL600	Serious (1) Minor (4) None (75)	121	Location, time, intensity accuracy (pilot and/or controller)
7/17/2015	ANC15FA049	Cessna 207A	Fatal (1) Serious (4)	135	Dissemination (operator)**
8/7/2015	OPS15IA020	Airbus A320-211	None (124)	121	Dissemination (controller)
8/26/2015	ERA15FA325	Cessna 310R	Fatal (1)	91	Solicitation, dissemination (controller)
11/9/2015	ERA16FA035	Cessna 441	Fatal (2)	91	Solicitation (controller)*

†PIREP concerns identified during these investigations may be unrelated to the cause of the accident and may not involve procedural or regulatory noncompliance. In most cases, the concerns are discussed in the Weather Factual Report and/or the Air Traffic Control Factual Report in the docket for each accident.

* This accident was under investigation at the time of this report. This preliminary information is subject to change and may contain errors.
** This accident was under investigation at the time of this report, but the docket is open for public view.

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