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Human Factors Guidance for the Display of Pilot Reports (PIREPs) on Information Display Systems

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16. Abstract

The purpose of this study is to develop an understanding of how Pilot Reports (PIREPs) are displayed and used by Air Traffic Controllers. This document provides a summary of the terminal and en route PIREPs system and identifies how human factors principles might be implemented to improve PIREPs in the future. The summary is based on interviews with controllers at Philadelphia International Airport, review of PIREP documentation, and the authors' knowledge and expertise.

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Executive Summary

Pilot reports (PIREP) provide critical observational weather information to all users in the National Airspace System (NAS). PIREPs are provided by pilots to air traffic controllers, who then disseminate the information to other users of the NAS. This shared information is used to enhance safety by creating a more complete picture of weather conditions for specific areas of the NAS. For example, aircraft reporting turbulence for a specific altitude enable controllers to plan to avoid that altitude for other aircraft.

Controllers are required to solicit and disseminate PIREPs on a regular basis in certain weather conditions. A well-designed information system will enable controllers to effectively manage PIREPs while focusing on their primary tasks. The current system for PIREP management tends to be workload intensive, cumbersome to manage, and error prone. For example, in the current system, because of lack of interconnectivity, the same information must be entered multiple times via free text. This creates extra workload and allows for additional opportunities for data-entry errors. Effective system design would address these and other issues to streamline PIREP management-related tasks.

This document provides a summary of the terminal and en route PIREP delivery systems, their human factors pros and cons, and guidance as to how to improve the procedures and display systems. We also provide recommendations as to how this guidance can be applied for NextGen projects, such as the Enterprise Information Display System and Data Communications. Finally, we summarize interviews conducted by the research team with terminal controllers and managers stationed at the Philadelphia International Airport.

1. Introduction

Pilots, air traffic controllers, airport managers, and airlines all rely on having accurate and up-to- date aeronautical information to operate safely in the National Airspace System (NAS). A key part of maintaining safety includes aiding pilots in avoiding bad weather. Turbulence, ice, and clouds make flight more dangerous and less pleasant for pilots. Pilot reports (PIREPs) are an important contribution to the weather information that pilots and controllers use to keep the NAS safe.

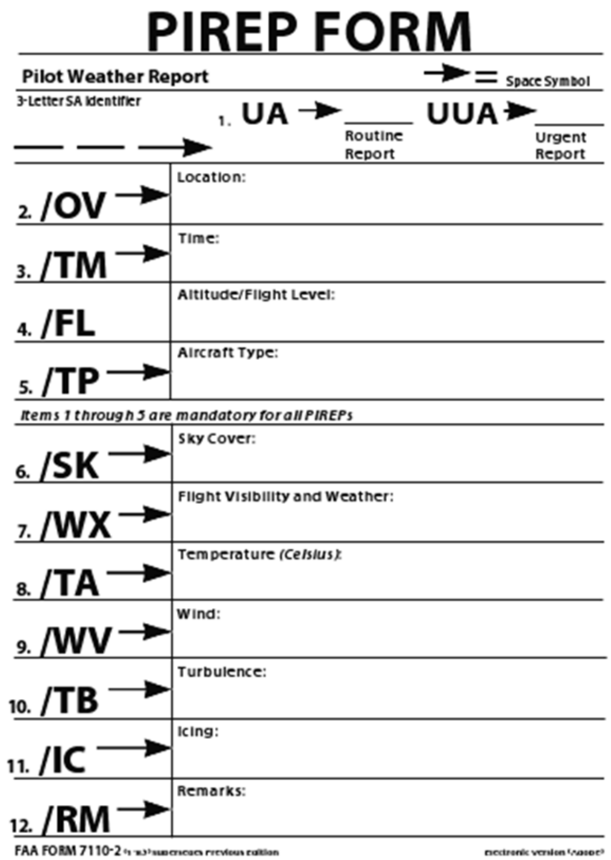
Pilots get broad weather information from Significant Meteorological Advisory (SIGMETs), Airmen's Meteorological Advisory (AIRMETs), and Forecast Areas, but PIREPs provide specific, detailed information about the weather conditions in a localized area. Weather forecasters use PIREPs to increase the accuracy of weather products, such as SIGMETs, by validating forecasted conditions or fine-tuning forecasts when predicted conditions do not occur. Additionally, pilots can obtain weather information from the Automated Weather Observing System (AWOS), which automatically broadcasts weather conditions in the vicinity of airports obtained by tuning in to specified radio frequencies. Weather conditions, not necessarily located proximally to airports, may also be attained from the Automated Surface Observing System (ASOS), which is updated hourly. Air traffic controllers use these reports to advise pilots when adverse conditions are along their routes or to route aircraft away from adverse conditions.

This document discusses how PIREPs are relayed to and used by controllers from a human factors standpoint. Controllers are largely occupied by communicating with pilots and moving them safely through the NAS; their time for accessing, interpreting, and communicating extra information like PIREPs is at a premium. Thus, it is important that the transmission of PIREPs be efficient and that the PIREPs themselves be easily read and communicated by controllers. This document will describe how PIREPs are currently transmitted and displayed to controllers, related human factors guidelines, and how these guidelines might be implemented in future system updates.

1.1 The Current PIREP System

PIREPs may be given by pilots or solicited from controllers at any time, but there are requirements on each as to when reports are required. For instrument flight rules (IFR) pilots, this requirement is listed in FAA Aviation Regulation Part 91.183 IFR Communications, which states in part, "the pilot in command of each aircraft operated under IFR in controlled airspace…must report the following as soon as possible—(b) Any unforecast weather conditions encountered".

For air traffic controllers, the requirements are covered in JO 7110.65V Air Traffic Control para 2-6-3 PIREP INFORMATION. "a. Solicit PIREPs when requested or when one of the following conditions exists or is forecast for your area of jurisdiction:" The document lists the specific conditions under which a controller must request a PIREP, but they can be summarized as when weather conditions are hazardous. Controllers may record PIREPs using a standardized form on paper (Figure 1), FAA Form 7110-2 for entering PIREPs. Alternatively, the controller or supervisor may enter the PIREP directly into their Information Display System (IDS). These systems vary between terminal and en route facilities.


PIREP FORM

Pilot Weather Report → = Space Symbol

3-Letter SA Identifier

1. UA → ____ Routine Report UUA → ____ Urgent Report

2. /OV → Location:

3. /TM → Time:

4. /FL Altitude/Flight Level:

5. /TP → Aircraft Type:

Items 1 through 5 are mandatory for all PIREPs

6. /SK → Sky Cover:

7. /WX → Flight Visibility and Weather:

8. /TA → Temperature *(Celsius)*:

9. /WV → Wind:

10. /TB → Turbulence:

11. /IC → Icing:

12. /RM → Remarks:

FAA FORM 7110-2

Figure 1. FAA Form 7110-2 for entering PIREPs.

For the terminal environment, four different IDS systems are currently in use. These are:

- Systems Atlanta-Information Display System (SAIDS) 4
- SAIDS 5
- ASOS Controller Equipment (ACE)/Integrated Display System (ACE-IDS)
- NAS Information Display System (NIDS)

The four IDS systems each house several information services on one common display. The four IDS systems share commonalities regarding the manner information is received and displayed to the controller. The information selections are generally determined and managed by the facility's system administrations and, therefore, outside the scope of the controllers' responsibilities. The information includes, but is not limited to, altimeter setting, runway visual range, ASOS, notice to airmen (NOTAM), SIGMET, Meteorological Aerodrome Report (METAR), wake turbulence, and other weather data sources. Appendix A contains a list of additional services or features accessible via these display systems. In many cases, these services originate from independent systems that do not connect with other systems, such as the Internet, because of security concerns. Therefore, these services may or may not automatically update in the IDS. In these cases, the information must be accessed separately for each service and be manually input into the IDS. This type of manual data entry contributes unnecessarily to workload and is associated with manual checking and entry errors, such as information delay, selection errors, missed information errors, typographical errors, etc.

For the en route environment, the En Route Information Display System (ERIDS) was deployed to all 20 Air Route Traffic Control Centers (ARTCCs) as a way to replace paper documents and provide a more efficient way for controllers, supervisors, and traffic-management specialists to search for information. ERIDS is a web-based information system that provides real-time access to aeronautical data, weather data, airspace charts, controller procedures, sector binder information, PIREPs, and NOTAMs.

Both the paper and electronic template include the same information fields. Both the paper and electronic format serve to standardize the information and to format it into coded abbreviations. Examples of the paper form and the ERIDS entry screen are shown Figure 1 and Figure 2, respectively. Controllers are required to ensure that all PIREPs include the first five elements: classification, location, time, altitude/flight level, type aircraft, and one or more of the remaining elements. Elements 6–12 are included as applicable to the conditions. Figure 3 describes each PIREP code, its associated element, and the related element content description.

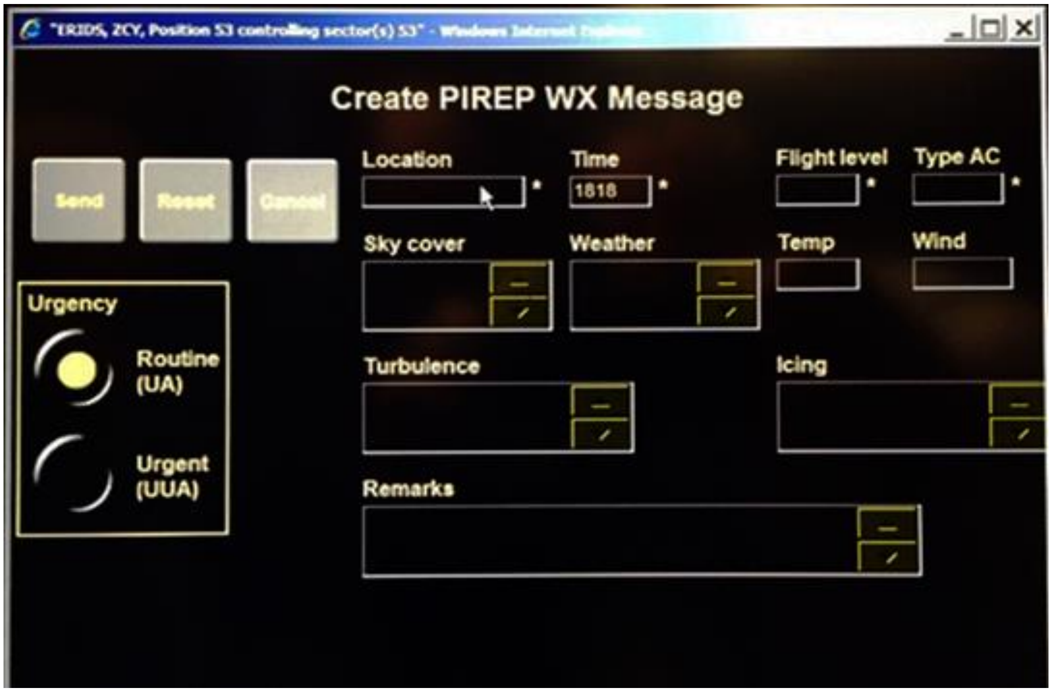


Figure 2. The PIREPs creation tool in ERIDS.

Encoding Pilot Weather Reports (PIREPS)			
1	XXX	3-letter station identifier	Nearest weather reporting location to the reported phenomenon
2	UA	Routine PIREP, UUA-Urgent PIREP.	
3	/OV	Location	Use 3-letter NAVAID idents only. a. Fix: /OV ABC, /OV ABC 090025. b. Fix: /OV ABC 045020-DEF, /OV ABC-DEF-GHI
4	/TM	Time	4 digits in UTC: /TM 0915.
5	/FL	Altitude/Flight level	3 digits for hundreds of feet. If not known, use UNKN: /FL095, /FL310, /FLUNKN.
6	/TP	Type Aircraft	4 digits maximum. If not known, use UNKN: /TP L329, /TP B727, /TP UNKN.
7	/SK	Sky cover/Cloud layers	Describe as follows: a. Height of cloud base in hundreds of feet. If unknown, use UNKN. b. Cloud cover symbol. c. Height of cloud tops in hundreds of feet.
8	/WX	Weather	Flight visibility reported first: Use standard weather symbols; intensity is not reported: /WX FV02 R H, /WX FV01 TRW.
9	/TA	Air temperature in Celsius (C)	If below zero, prefix with a hyphen: /TA 15, /TA -06.
10	/WV	Wind	Direction in degrees magnetic north and speed in six digits: /WV 270045, WV 280110.
11	/TB	Turbulence	Use standard contractions for intensity and type (use CAT or CHOP when appropriate). Include altitude only if different from /FL, /TB EXTREME, /TB LGT-MDT BLO 090.
12	/IC	Icing	Describe using standard intensity and type contractions. Include altitude only if different than /FL: /IC LGT-MDT RIME, /IC SVR CLR 028-045.
13	/RM	Remarks	Use free from to clarify the report and type hazardous elements first: /RM LLWS -15KT SFC-030 DURC RNWY 22 JFK.

Figure 3. PIREP message composition format.

The PIREP elements are composed of text in an all-capital letter format, which is an artifact from teletype systems used by the U.S. Weather Bureau beginning in 1928. Each PIREP element is separated by a forward slash (/). The elements are composed of contractions and abbreviations used to standardize and shorten the messages. This requires the user to decode the message by referring to a list of contractions if they are not already readily known. For example, weather elements will be reported using one or more of the standard surface weather reporting symbols shown in Table 1. A comprehensive list of FAA contractions is found in ORDER JO 7340.2D Contractions (FAA, 2013), which contains more than 500 pages of word and phrase contractions. A more detailed description of PIREP input along with a definition of terms can be found in the Aeronautical Information Manual (FAA, 2016). The PIREP elements generally take some familiarization training to learn to encode and decode the PIREP messages.

Table 1. Standard Surface Weather Reporting Symbols

TYPE	SYMBOL
Drizzle	DZ
Dust	DU
Fog	FG
Freezing rain/drizzle	FZRA/FZDZ
Funnel Cloud	FC
Hail <¼ inch	GS
Hail >¼ inch	GR
Haze	HZ
Mist	BR
Rain	RA
Rain Showers	SHRA
Smoke	FU
Snow	SN
Snow Showers	SHSN
Thunderstorms	TS/TSRA
Tornado	+FC
Volcanic Ash	VA
Waterspout	+FC

Figure 4 is an example of a complete, encoded PIREP as shown to the controllers. A PIREP with the field descriptions called out is shown in Figure 5. Each data field is separated by a forward slash and is presented in the same manner for each PIREP. The example in Figure 4 can be decoded in the following manner: A routine PIREP located on a 230-degree radial, 10 nm from the Appleton VOR at 15:16 UTC, is reported by a Beechcraft Super King Air 200 at 8,500 ft. The BE20 reports that the sky condition is a broken layer of clouds with tops at 6,500 ft; flight visibility is at 3 statute miles with moderate mist; air temperature is 2 degrees Celsius; wind is 230 degrees at 8 knots, with light turbulence and trace rime icing. The remarks field is used to report phenomena that are considered important but do not fit in any of the other areas. In this example, the Beechcraft reports towering cumulus west to northeast.

```
UA/OV APE230010/TM 1516 /FL085/TP BE20
/SK BKN-TOP065/WX FV03SM BR/TA 02/WV 23008KT
/TB LGT/IC TRACE RIME/RM TCU W-NE
```

Figure 4. Example of a pilot weather report.

Classification/Location/Time /Altitude or Flight Level/Type Aircraft
/Sky Condition/Weather-Flight Visibility/Air Temperature/Wind
/Turbulence/Icing/Remarks

Figure 5. The PIREP field description.

The sharing flow of PIREPs is diagrammed in Figure 6. Pilots create the PIREP, located at the top of the diagram. The PIREP may originate from the pilot or be requested by the controller. Once the information has been given to the controller, the controller will then propagate the report to a variety of recipients. The controller will communicate the PIREP to other pilots likely to be impacted. For example, if a pilot tells a Terminal Arrival Route Control (TRACON) controller that there is turbulence on departure, the controller will tell other pilots on the same route that there is turbulence. The controller will also call other controllers who are operating relevant airspace to inform them of the PIREP. Following the same example, the TRACON controller may call an en route controller to inform them of turbulence for arriving flights so that the en route controller can plan accordingly.

These interactions make up most of the controllers' practical use of PIREPs. However, controllers also pass the reports forward for logging and further distribution. Terminal controllers communicate the PIREP to their supervisor, who then gives the report to the ARTCC (except in Alaska, where reports go to Flight Services; JO 7110.705). The supervisor may also forward the PIREP to the Traffic Management Unit, if one is on site.

En route controllers will forward PIREPs to a meteorologist in the Center Weather Service Unit (CWSU). En route controllers can also enter PIREPs directly in ERIDS, where they will be sent to a CWSU meteorologist who can broadcast the PIREP through the system as a general information (GI) message.

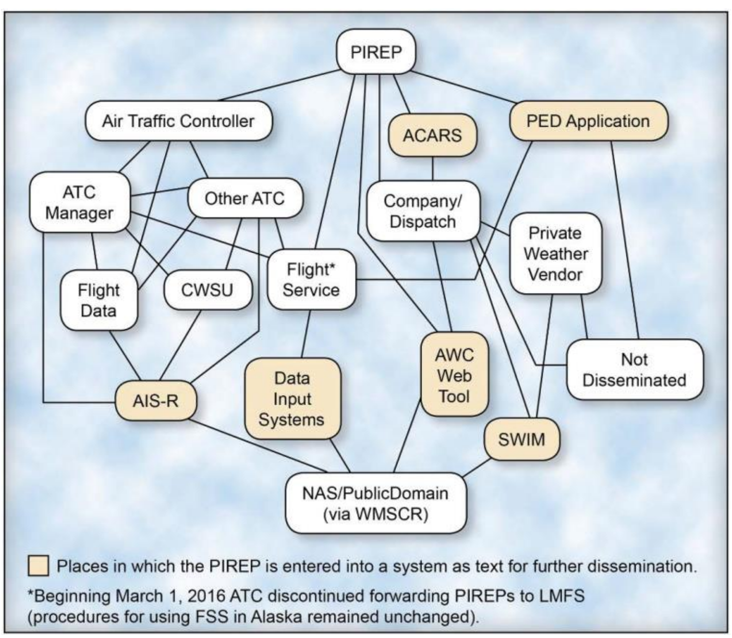


Figure 6. Possible PIREP information flow (figure taken from NTSB, 2017).

1.2 How PIREPs are Transmitted to Controllers

Air traffic controllers obtain broad weather information from a pre-shift briefing. They then receive information directly impacting their area of control, including any relevant PIREPs, during their position briefing. This would include areas of specific interest, such as altitudes that may be experiencing turbulence. Controllers are required to keep PIREP information updated hourly when certain weather conditions exist. Pilots commonly check onto a new frequency reporting the ride conditions (e.g., smooth ride, moderate chop) along with their aircraft identification and altitude information. Pilots are also required to report unforecasted weather observations as they occur.

If no unsolicited PIREPs are received during specified weather conditions, controllers are required to obtain PIREPs directly from the pilot on an hourly basis. If a PIREP has been requested by another facility, the controller may instruct the pilot to deliver it directly to that facility. The controller forwards the PIREP to the facility manager, who in turn forwards it to the CSWU meteorologist. The CSWU ensures that the sectors in the Center, the towers, and TRACONs are kept up to date on significant weather that may affect their areas of responsibility.

1.2.1 Terminal Controllers

According to the JO 7110.65V Air Traffic Control paragraph 2-6-3, terminal controllers are required to relay all operationally significant PIREPs to:

- the appropriate intra-facility positions, such as adjacent sectors impacted by the weather conditions;
- the Flight Service Station (FSS) serving the area in which the report was obtained; and
- other concerned terminal or en route air traffic control (ATC) facilities, including non-FAA facilities, such as airline dispatchers, military operations, and airport operators.

Although general guidelines are outlined in the JO 7110.65V, each facility has a standard operating procedures (SOP) document, which details roles and responsibilities, and defines procedures for overall operations. These SOPs may vary slightly from facility to facility. A specific example taken from Boston Terminal's SOP document (FAA, 2014) outlines the roles and responsibilities regarding PIREPs.

> *"The Front Line Manager/Controller in Charge (FLM/CIC) is responsible to ensure that PIREPs are solicited and disseminated for each hour that the weather conditions exist or are forecasted to be as stated in FAAH 7110.65.*
>
> *The Traffic Management Coordinator (TMC) is responsible to forward the PIREP to the appropriate facility in a timely manner. If no TMC is on duty, the FLM/CIC is responsible to ensure PIREPs are disseminated in a timely manner.*
>
> *The FLM/CIC shall ensure that applicable SIGMETS and Center Weather Advisories (CWAS) are disseminated as soon as possible. Applicable SIGMETS and CWAS must then be posted on the appropriate IDS5 page(s) by the TMC. If a TMC is not on duty, SIGMETS and CWAS must be posted by Flight Data (FD)."*

In the terminal environment, controllers generally track their hourly solicitation by manual record-keeping on a scratchpad. It is incumbent on controllers to keep track of how often a PIREP is needed simply by referring to the times written on paper kept near their workstations.

This type of information is verbally relayed from controller to controller during the relief briefing. There is no system-based reminder or way of tracking whether the solicitation requirements are met or whether the information is passed on to required personnel.

The PIREPs are disseminated by manual entry into an IDS. Most Airport Traffic Control Towers (ATCT) and TRACON facilities use one of four information displays. As mentioned in section 2, these are: SAIDS4, SAIDS5, ACE-IDS, and NIDS. The NIDS system is intended to replace SAIDS4 and ACE-IDS.

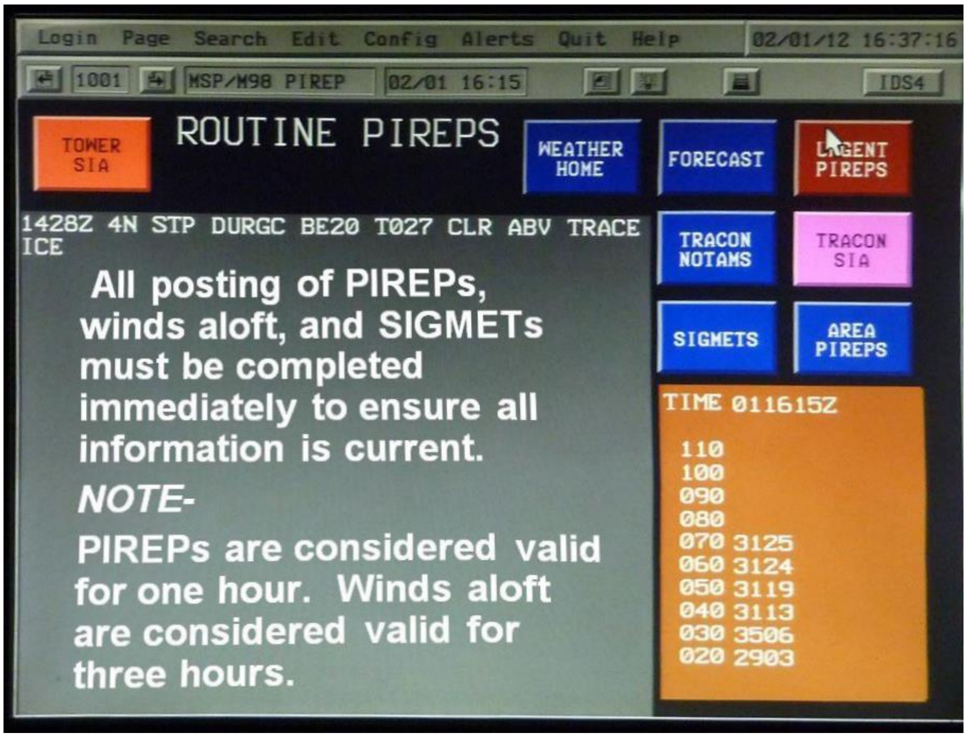


Figure 7. Example of an IDS4 with Area PIREPs and URGENT PIREPs buttons taken from a facility training package. Note: The procedure included in this training message may not apply to all facilities.

The four systems are described as “electronic binders” for which multiple sources of data can be combined and displayed on a common system. They have much in common with one another in the way information is received and displayed to the controller. The controller has limited control over the selection of information, which is determined by the facility’s system administrator. These are also closed systems, which do not currently communicate with ERAM. This would necessitate an additional manual entry of the PIREP for any affected en route sectors.

In addition to entering the PIREPs into an IDS, an individual must then enter the same PIREP into the Aeronautical Information System-Replacement (AIS-R). Terminal facilities previously submitted PIREPs to Lockheed Martin Flight Service for entry and dissemination; however, effective March 1, 2016, facilities were required to enter the PIREPs into AIS-R themselves. 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 (NTSB, 2017).

1.2.2 En Route Controllers

According to JO 7110.65W Air Traffic Control paragraph 2-6-3, en route controllers are required to relay all pertinent PIREP information to concerned aircraft in a timely manner. They are also required to relay all operationally significant PIREPs to the CSWU meteorologist (FAA, 2015).

When controllers receive weather information from pilots, they may take one of two actions. They may enter the information on the paper PIREP form (see Figure 1) and deliver it to their supervisors. Alternatively, controllers may enter the PIREP directly into the ERIDs system (see Figure 2). ERIDS allows for automatic distribution of PIREPs because it can access information over the Internet. There may still be some intervention in the system, for example by a manager setting certain filters, but ERIDS provides a much more automated system than SAIDS or NIDS. The PIREP then flows to the CSWU meteorologist who is responsible to ensure the PIREP is distributed to all ARTCC sectors. The PIREP must be entered separately into AIS-R, which acts as the information hub delivering aeronautical information to other users within the NAS.

Available PIREPs are displayed in the GI message view of the radar associate's (RA's) position of the En Route Automation Modernization (ERAM) Decision Support Tool (EDST) (see Figure 8). Figure 8 shows the EDST with windows open for a weather report (e.g., SIGMET), a GI, and altimeter settings. The GI tab on the top menu bar toggles on and off. The RA controller has the option of using the EDST as the source of the PIREP display or printing the GI messages onto a flight progress strip. The flight progress strip can be placed in the flight strip bay as a reminder to the controller to relay PIREP information as required. Figure 9 shows an example of an en route control position with the ERIDS console mounted on a moveable arm between the radar and RA positions.

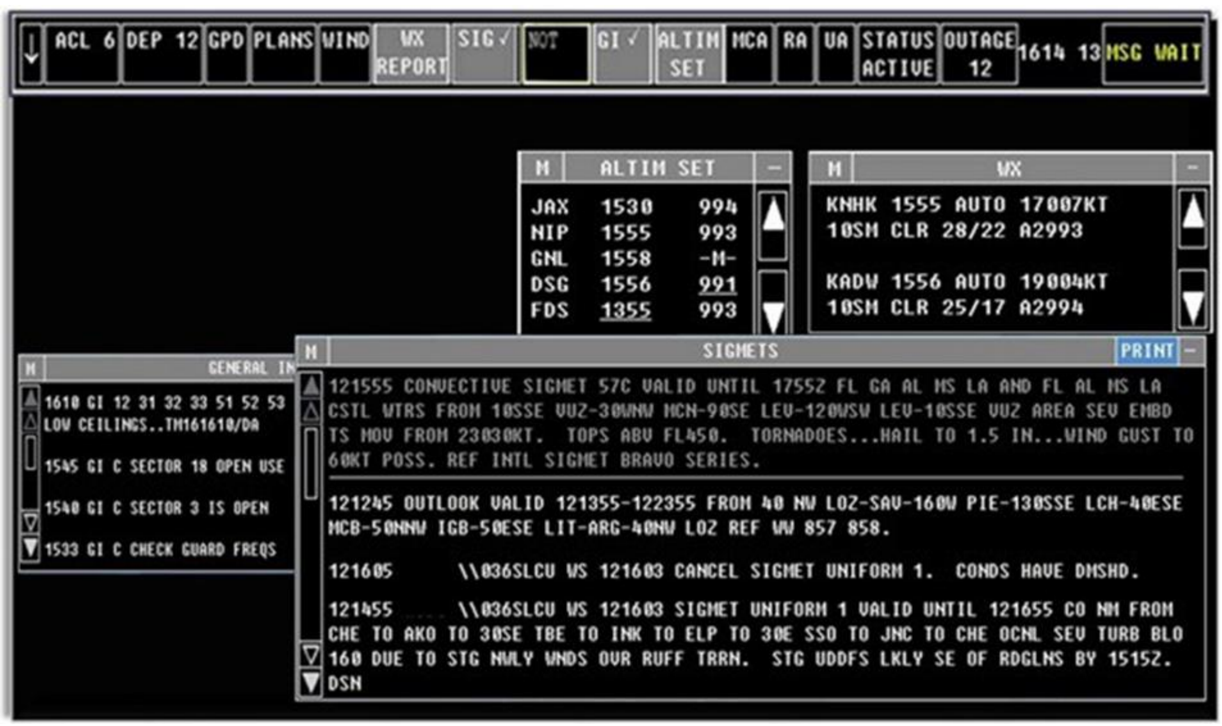


Figure 8. ERAM Decision Support Tool (EDST) interface.

Figure 9. ERIDS console mounted on a moveable arm between the radar and radar associate position.

1.3 How PIREPs are Used by Controllers

Controllers use PIREPs in conjunction with other weather-decision-support tools to make informed decisions regarding traffic flow. Controllers also communicate the reports directly to any pilots that may be affected by the weather condition identified in the PIREP. If needed, controllers will communicate with adjacent sectors if affected aircraft are not in their control. For example, if a departing aircraft transitioning from terminal airspace to an en route sector reported turbulence upon checking on to the en route frequency, the en route controller would relay that information back to the terminal controller. This would enable the terminal controller to either modify traffic flow to try to avoid the area or relay the information to pilots who will be traveling through the affected area. PIREPs are also useful when reporting good conditions. This is especially true when icing and turbulence are forecasted for the area. Controllers often use good ride reports to advise aircraft of altitudes that may be less turbulent. Good reports are especially important in cases of icing, in which pilots may need to make time-critical decisions to avoid unsafe conditions.

Once a PIREP is in the system, there is no automated way to determine whether the report is still valid. As mentioned in section 2.1.1, it is incumbent on the controller to make this determination by looking at the time of the older report to ensure it was recorded within the last hour. There is no automated prompt that ensures reports are solicited within the hourly timeframe. The controller must also assess whether any newer PIREPs either substantiate or negate the older report. In addition, all PIREPs, even those with outdated information, remain in the system unless manually deleted.

1.3.1 Terminal Controllers

Terminal controllers or their frontline managers manually enter the PIREPs into the IDS to view during operations. They must also enter the same information in the AIS-R for dissemination to other positions and facilities. At times, they keep track of PIREPs through written notes by their position. Even if entered into the IDS, the controllers have little interaction with the PIREP subsequent to entry, other than to select the PIREPs button to view reports as needed to relay information. The IDS has different buttons for urgent PIREPs and area PIREPs. The controllers will select PIREPs at any time they feel they need to view this information; however, there is no system notification. This is in contrast to the en route environment, which uses the ERAM system to exchange information between users.

1.3.2 En Route Controllers

En route controller interaction with PIREPs within the ERAM system is relatively limited. En route controllers can access previously entered PIREPs via the GI Messages View of ERAM (see Figure 10). The GI Messages are described in detail in the EAB1200 En Route Automation Modernization Air Traffic Manual: RA-Position User Manual (FAA, 2011). New messages are indicated by a notification on both the GI Messages View and the GI toolbar button. The view can be suppressed via the GI toolbar button. The GI View automatically expands or contracts when an entry is added or deleted. A scroll bar is displayed when the number of lines exceeds the number specified in the GI Messages View Menu LINES option.

When the controller selects a PIREP, a pop-up menu with an option to “FORWARD,” “DELETE,” or “PRINT” appears.

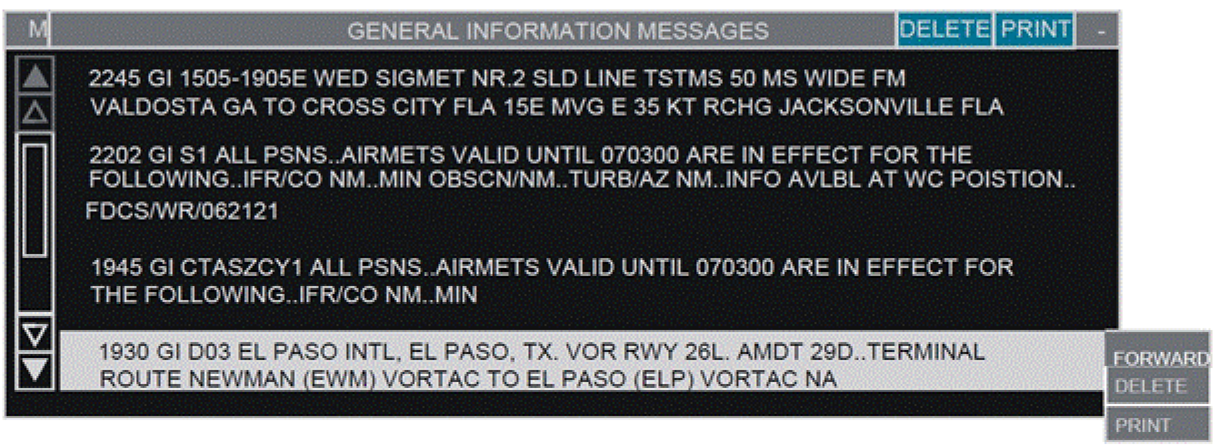


Figure 10. ERAM General Information Messages View (EAB1200 En Route Automation Modernization Air Traffic Manual: RA-Position User Manual, 2011).

PIREPs may be forwarded from one control position to another using the “FORWARD” button on the GI Messages View pop-up menu. When the controller selects the “FORWARD” button, a forward-position selection menu appears, displaying all specified sectors/areas (see Figure 11). In the example shown in Figure 11, the gray text indicates that they have had the GI message entry routed to them previously.

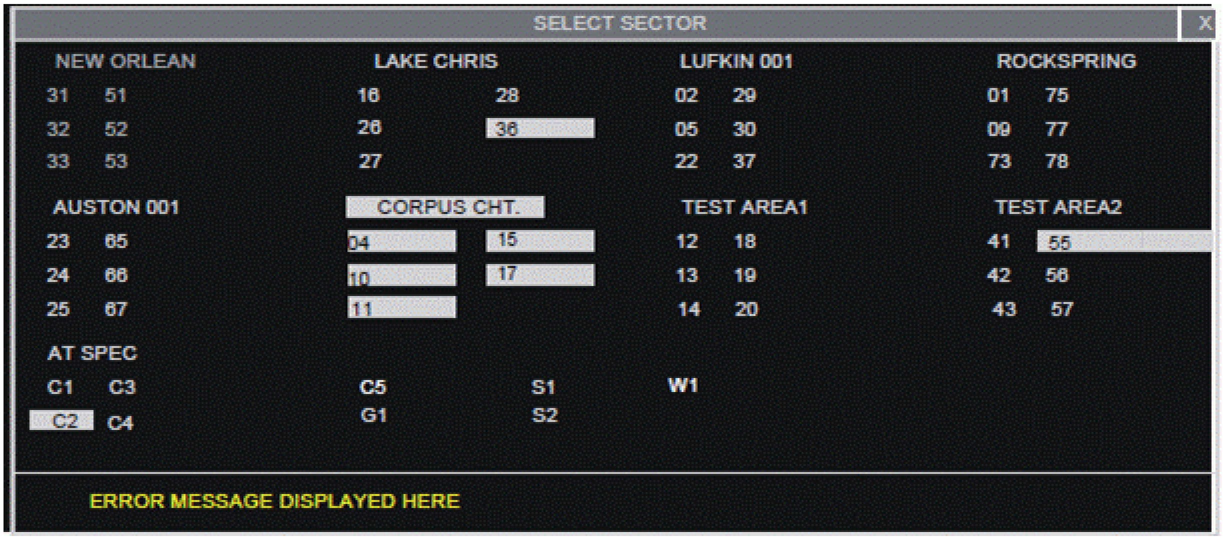


Figure 11. Forward position selection window.

Controllers also can adjust the font size, number of lines, and text brightness of the General Information Message View. If paper strips are in use, the controller has the option of printing the PIREP and adding it to the strip bay as a memory cue to issue reports as required.

1.3.3 Usage Elements for Terminal and En Route

Although the flow of information and data processing may differ slightly between terminal and en route facilities, both must solicit, record, and handle PIREPs as outlined in the JO 7110.65 paragraph 2-6-2. The requirements for solicitation and relay are slightly different between terminal and en route environments. For example, terminal controllers must “ensure that at least one descent/climb out PIREP, including cloud base/s, top/s, and other related phenomena, is obtained each hour.” The en route controllers have additional requirements to gather PIREPs when specified conditions exist. Likewise, the handling of PIREPs is outlined for both en route and terminal controllers to relay all information to aircraft, facility weather coordinators, intra-facility positions, or flight service stations as applicable. For both terminal and en route facilities, the controller must take an action to view PIREP messages by either selecting the view on their information display or printed PIREP strip.

1.4 Summary Evaluation of Current Information Display Systems for PIREPs

The terminal environment currently has four different information-display systems, each using different hardware and software configurations to display common information. Procedures for how to manage PIREPs may vary slightly from facility to facility.

The PIREPs are displayed in a consistent manner in terms of information format. The controller knows that each PIREP will contain the same type of information in the same order of the report. In this way, the message conforms to a standard mental model to assist the controller in quickly gathering necessary information. The message is formatted similarly to a flight strip.

Currently, PIREPs must be manually entered into two different systems. This contributes to additional and unnecessary workload, while increasing the probability for manual-entry error. Manual-entry tasks that require repetitive and tedious housekeeping duties are often shed during times of high workload, thereby increasing the risk that critical PIREPs will be missed.

The presentation of the text relies heavily on the use of contractions. The lack of plain language, compounded with the use of all capital letters, is less than optimal for normal comprehension. In addition, critical substitution or input errors may occur when the user attempts to enter information (such as using “MDT” instead of “MOD” for moderate). The system allows users to input these erroneous contractions without user feedback, but later in processing, they are not recognized by the software, and the entire message is dropped. Thus, a PIREP can be lost without warning because of an unnoticed typo.

En route operations are similar to the terminal environment in that the controller must either enter the PIREP into ERIDs or complete a paper PIREP form for someone else to enter. In either case, the initial report must be entered into ERIDs. The information must then flow to the CWSU. Although the CWSU meteorologist can view the PIREP in ERIDS, it must be re-entered into an automated weather system for its distribution because the two systems do not communicate. ERIDS does have capabilities that allow message distribution to several sectors, facilities, and users simultaneously. Because the PIREPs are binned with the “General Messages,” they are mixed in with other types of GI messages, and the controller must scroll through different types of information to find specific PIREPs. Ideally, PIREPs could be better organized so that the controller can gain required information at a glance.

2. Human Factors Best Practices

Although there are no known studies relating directly to controller use of PIREPs, there are some general guidelines that could apply to their design, display, and general use.

2.1 Broad Guidelines

Drawing upon the Human Factors Design Standard (Ahlstrom & Longo, 2003), Yuditsky, Freidman-Berg, and Smith (2004) developed design standards and guidelines for display systems using structured interviews and user workshops. Although not specifically referencing PIREPs for the terminal environment, some of these guidelines apply to their use.

The first guideline is that information should be accessible. Yuditsky et al. (2004) refers to both physical accessibility and organizational accessibility. Physical accessibility refers to the ability of the controller to see, reach, and interact with the information in a timely manner.

Organizational accessibility refers to menus, levels, sublevels, organizational structure, information grouping, etc.

Controllers surveyed by Yuditsky et al. (2004) reported that many systems were poorly organized, cluttered, and counterintuitive; had too many levels; and lacked an index (Ahlstrom, 2016). Because of the extent of different types of information consolidated on the IDS, organization is an enormous challenge; however, it is critical. Poorly organized systems may present a big enough obstacle to controllers that they become of little use. Yuditsky recommends customization for specific user roles, which allow for quickly accessing common job-related tasks. They also recommend co-locating information, using like-colored links to group-related information, and using secondary organizational schemes (e.g., by subject matter).

Yuditsky et al. also found a lack of consistency among displays between and even within facilities. Although some adaptations are necessary because of the variable facility needs and operations, basic display schemes should be applied to all systems. This can reduce training time and improve user access by allowing transfer of expectations from display to display.

An efficient and intuitive search function is a critical component of the IDS. Because of the large amount of data housed within the IDS, not all information is or should be included in prominent areas of the main screen. An effective search capability will allow the controller to recall specific information as needed without having to navigate through numerous menus.

The second guideline presented by Yuditsky et al. is that information should be current. This is obviously important for PIREPs because weather information is very dynamic. The PIREP information should be organized and presented so that the controller has access to the most recent information for a given location. Because the controller is also required to solicit PIREPs on an hourly basis, there should be some means to track whether this has occurred.

In March 2017, the NTSB released a Special Investigation Report to improve PIREP submission and dissemination. The report found that deficiencies within the system fall into two broad categories: submission deficiencies and dissemination deficiencies. Although submission deficiencies fall largely within the pilot domain, the dissemination deficiencies point to needed improvements within the air-traffic-management domain. The report states:

"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."*

The National Transportation Safety Board (NTSB) (2017) 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."

The NTSB emphasizes the importance of obtaining good weather reports and adverse weather reports, citing incidents that may have been averted if good weather PIREPs were available. Controllers may not prioritize the solicitation or dissemination of good weather reports over other controller tasks; therefore, this type of information goes largely ignored. The NTSB report calls out noncompliance with current solicitation requirements. Adverse weather increases the demand on controller workload, which may lead to neglect and noncompliance of lower priority tasks, such as solicitation of PIREPs. They also state that 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. Therefore, although the NTSB calls for an increase in PIREP volume, actual practice is potentially lower than even the minimum requirements.

In addition, the NTSB report cites inadequate dissemination of weather information, specifically failure to disseminate weather in a timely manner, failure to disseminate complete weather information, and failure to recognize PIREP urgency.

2.2 Specific Recommendations

Specific recommendations for the PIREP reporting system draws upon some of the broad principles detailed in section 2.1: primarily, making the PIREPs accessible means that they must be available to the users. Availability can break down at several points in the PIREP information process.

Encourage more PIREPs

PIREPs must be solicited by controllers or volunteered by pilots. The more information gathered, even in clear conditions, the better potential for a more complete picture of conditions in the NAS. Although procedures require controllers to ensure that they receive at least one PIREP per hour in less than optimal conditions, controllers may be more willing to collect and report more PIREPs if the system allows for more efficient data entry and retrieval.

Underscoring this recommendation, the NTSB released a report investigating the deficiencies of the current PIREP system (NTSB, 2017). They recommend that some of the operational procedures available to controllers are ambiguous or may conflict with other procedures and guidance. In addition, specific NTSB recommendations include:

- implement scenario-based user training for the submission and dissemination of PIREPs; and
- increase the overall number of PIREPs. PIREPs are a critical source of observational data for conditions aloft; therefore, increasing PIREPs in quantity and quality will enhance situation awareness of weather conditions.

Streamline the PIREP entry process

The current system should be streamlined to enter PIREPs into the system quickly and reduce the number of points of potential error. An obvious, and critical, improvement to the current system is to reduce the number of times the same information is entered into the system to a single point of entry. Single entry would decrease the number of chances for input errors, decrease workload, and make the information available to all users simultaneously.

Currently, the radar controller has secondary access to the PIREP information and must rely largely on memory because PIREP information is not housed on the radar controller's primary display. This information is mostly managed by the RA controller. Potentially, a separate view or selectable map feature on the controller's main position could be explored to ensure that a radar position controller could easily correlate the position of an aircraft and its route of flight with that of the pertinent information without diverting their attention away from the surveillance display.

Improve system error handling

The system should be more error proof. The current system accepts erroneous inputs, without user feedback. For example, the system will accept incorrect abbreviation codes, but it will not disseminate messages that contain the errors. These PIREPs, therefore, are lost within the system. Compounding this issue is the use of free text to enter abbreviated codes. This system is error prone because it relies on controller memory to select the correct code and then also enter it without typos. Although the free text format allows for a lot of flexibility, it is unnecessarily work-intensive, particularly for common PIREPs that occur with regularity. A system that allows users to select predefined, common code strings or employs the use of a graphical user interface could improve the controllers' ability to enter PIREP information with less time and error. In addition, because the controllers' PIREP system is text based, and the Aviation Center's PIREP system is graphical, there is an increased potential for information to be lost or misrepresented between these systems. Text information must be converted to graphical information and vice versa. Having systems that communicate via a common language reduces the risk of information loss.

Improve PIREP readability

PIREPs should be readily decoded. Although this is much more critical for NOTAMs, which may contain large amounts of text, PIREPs still contain contractions that may not be familiar to the controllers. If this is the case, the controller should have the ability to easily decode the contraction (such as hovering over a contraction to expand the decoded text). Alternatively, the system should employ the use of plain language. Users, both pilots and controllers, have reported issues with encoding and decoding PIREP abbreviations. More modern systems have superseded the need to use the encoded information. Designing the system to use plain language will decrease the number of substitution errors. It will also decrease the amount of time users must take to process the information. Additionally, users will not need to use a lookup table to decode unfamiliar abbreviations.

Improve PIREP automation

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" (NTSB, 2017).

Improve PIREP organization

PIREPs should be organized for access at a glance. Currently, the GI message view is a catchall for various messages. Ideally, the PIREPs should be organized together, without the need to navigate through multiple pages or scroll through disparate types of information. Specific recommendations include organizing PIREPs by time and relevance with regard to geographic area, altitude, or other relevant parameters. A PIREP search function should enable controllers to quickly locate desired information without the need to scroll through superfluous data.

Improve PIREP system notifications

System notifications should be tailored to the user's responsibilities. This means that as PIREPs get updated and disseminated throughout the system, there should be some indication on the user's system that notifies them that a new PIREP is available. Notifications should be used in a way that will not impede the user's primary tasks, such as by covering up essential information, or requiring unnecessary acknowledgements to noncritical information. The inclusion of PIREP status information would allow notification of new PIREPs, provide an indication that a PIREP solicitation is due, and possibly automatically delete outdated reports to reduce the amount of unnecessary information contained within the system.

Provide PIREP graphical display capabilities

Because PIREPs are displayed in a text format, they must be interpreted by the controller for both content and spatial relationship to his or her area of control. A graphical display, similar to the displays available for pilot users on the FAA's NOTAM site (see Figure 12) and the Aviation Weather Center's PIREP site (see Figure 13), may be helpful for controllers to gain critical information at a glance. Displays such as these would help controllers better visualize which aircraft would be affected by the adverse condition by correlating an aircraft's position on the surveillance display with the symbol on the display depicting the PIREP.

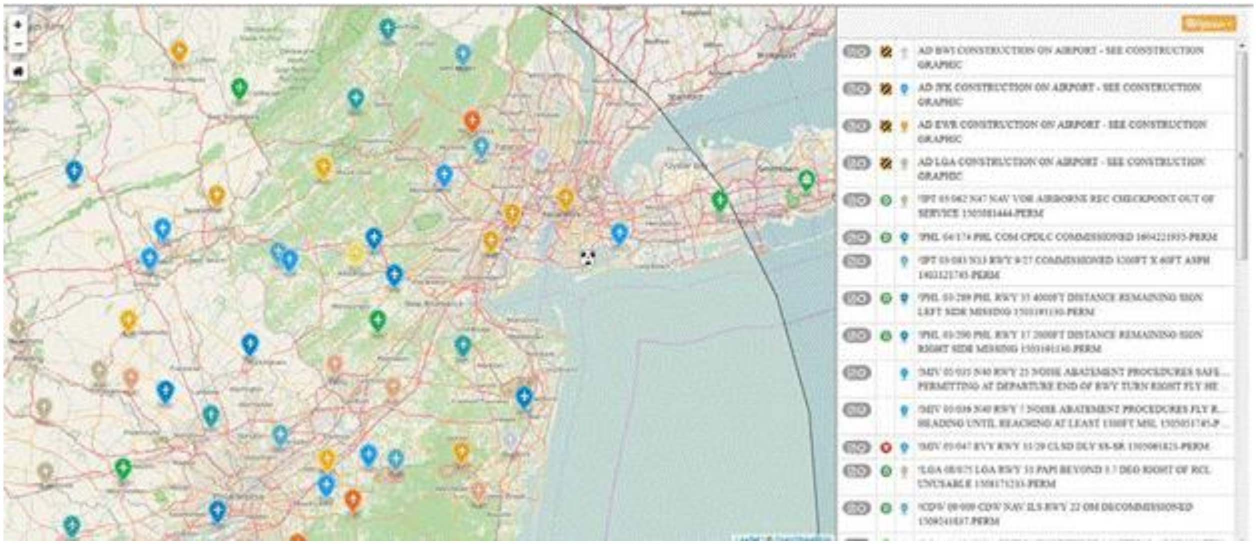


Figure 12. FAA NOTAM search page https://notams.aim.faa.gov/notam

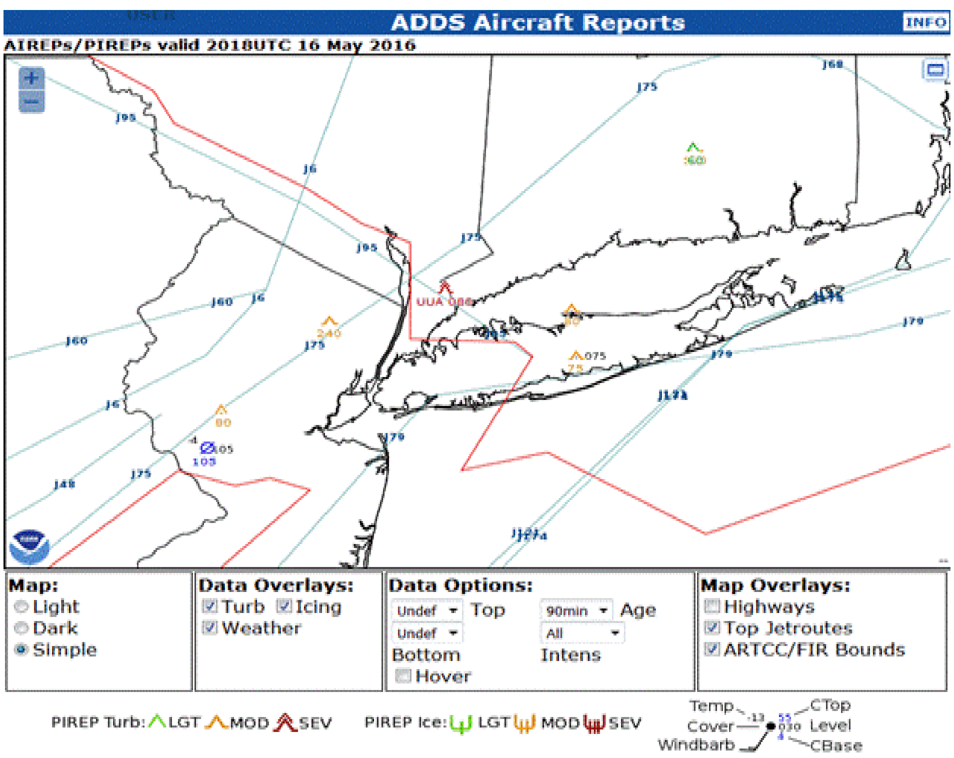


Figure 13. Aviation Weather Center PIREP display – https://www.aviationweather.gov/airep.

3. Air Traffic Controller Interviews – Philadelphia International Airport ATCT/TRACON

We conducted a group interview with three air traffic controllers, a systems supervisor, and an operations manager at the Philadelphia International Airport (KPHL) ATCT/TRACON. Philadelphia TRACON was using SAIDS-4 at the time, but was in the process of transitioning to NIDS, which was scheduled to take effect the next week. A list of prepared questions is provided in Appendix B.

The controllers and operations manager described a largely analog procedure for creating and disseminating PIREPs. When a controller receives a PIREP, he or she would write it down on one or two pieces of paper (such as the form in Figure 1). The PIREP would then be handed to the manager to be entered into AIS-R, and the copy (if made) would be kept as a reference or shared with controllers managing relevant sectors. They had no option to enter or receive PIREPs on their IDS; the process is done entirely on paper or verbally. The controllers commented that, in general, they did not think many PIREPs were practically useful.

Regarding other weather information, such as AWOS or ASOS, the controllers said they were able to use SAIDS-4 to access information when needed. However, not all controllers in the facility were aware of this fact, and not all who were aware knew the source of the information (e.g., AWOS). The only part of the weather reports they tended to use were wind speed and direction. In rare cases of an aircraft in trouble or a missed approach, the controller might use additional information, such as visibility.

The controllers made several recommendations for better display of weather information. They would greatly prefer to have a graphical display of PIREPs and other weather reports, and mentioned SkyVector (http://skyvector.com) as an example. They preferred that weather information be intelligently integrated with the scope so they would not need to take eyes off or try to correlate the IDS map with the scope map. This integration would include such features as toggling displays on and off, making notes, and drawing on the screen. The controllers noted that current automation for drawing and typing is slow and difficult to use. In terms of features, the controllers said that they might want to toggle or filter the weather displays by category, such as altitude and type of weather (e.g., icing). They would also like to receive and visualize additional information, notably winds aloft as opposed to the typical ground-level wind information currently available. One controller recommended that a weather history feature would be useful, to track storm movement for example, but another controller said that there was a way to accomplish this in SAIDS-4. This, along with the lack of knowledge of AWOS/ASOS access, suggests that better or additional training may be necessary.

Looking to the future, the controllers (particularly the two with previous en route experience) recommended that a short-term solution would be to equip ERIDS in the terminal environment. They preferred the greater automation present in ARTCCs. Long-term, they would like solutions to the problems mentioned above. Specifically, they would like a user-friendly graphical display of weather information that would allow them to maximize their eyes-on-scope time and keep clutter to a manageable level. The controllers would also prefer text in an easier-to-read format; they did not like the standard International Civil Aviation Organization abbreviations.

4. Looking Forward: Enterprise Information Display System

The FAA has recognized the limitation of the current information display systems and is exploring moving to a common platform known as the Enterprise Information Display System (E-IDS) as a part of its NextGen modernization program. Some of the NextGen programs, such as System Wide Information Management (SWIM), provide critical infrastructure that should benefit information flow to controllers. E-IDS, for example, is proposed to replace all the information systems currently in use and will rely on SWIM for automatic transmission of content like NOTAMs and PIREPs (Burke and Burnham, 2015; Burke, Wright, and Gill, 2015). Using SWIM, systems such as E-IDS and Data Communications (Data Comm) interface directly with the user. Thus, the discussion here will focus on E-IDS and briefly mention Data Comm as the NextGen systems that provide information directly to the controller.

In an attempt to improve the current IDS platforms, the FAA conducted a shortfall analysis of E-IDS (FAA, 2016) and identified three main problem areas with the legacy systems, including inefficiencies in data access and management. They report that "current capabilities to search and retrieve information are cumbersome and add to the workload levels of the controllers, FLMs, and TMCs who use the IDSs."

The shortfall analysis calls out this issue and states the E-IDS "must accept the manual entry of information from the service provider who first receives the information (e.g., the controller receiving a PIREP for turbulence) and automatically distribute the information, as appropriate, both internally within the facility and externally to other facilities." The shortfall analysis also states that "to support the situation awareness of all E-IDS users, E-IDS will indicate when information has been updated." The shortfall analysis also points to a lack of standardized procedures across facilities for entering and handling PIREPs. This leads to increased workload, duplication of effort, and potential increased opportunity for error.

Some specific recommendations generated in the E-IDS shortfall analysis underscore some general human factors guidelines identified in this document that would improve the usability of PIREPs. The guidelines include:

- single-point data entry;
    - reduce the number of times the same data must be entered into the system
- simultaneous data dissemination to all users;
    - automatically disseminate data to all users after the point of data entry
- shared situation awareness;
    - provide all users access to the same information in real time
    - automatically distribute information intra and interfacility
- automatically update information, hierarchy, and shortcuts;
    - reduce the need for manual data entry
- display status information for PIREPs;
    - indicate when information has been updated for shared situation awareness.
- provide controls on access to data (entry and edit only for authorized users), modern telecommunications, and systems interfaces;
- replace multiple IDS programs with a single common IDS program;
    - apply maintenance procedures and training across the different domains
- common architecture for common situation awareness.

Burke and Burnham, (2015) and Burke, Wright, and Gill, (2015) describe the general plan for the system. The E-IDS promises to automate delivery of information (such as NOTAMs and PIREPs) to controllers and back out from controllers to other personnel via SWIM. The E-IDS also promises to ease access to information, although there is not enough specific information to evaluate that claim. That said, Burke and Burnham (2015) estimate that the various improvements provided by E-IDS (e.g., automatic transmission of information, smoother workflow, and easier access/search of documents) should reduce en route controllers' document access time by two-thirds, oceanic controllers' document access time by nearly 90%, and terminal/tower controllers' document access time by half. The authors also recommend benefits for managers in data-management tasks, such as updating charts, which should benefit frontline controllers by ensuring that data are more current and by giving managers more time to provide other support.

Data Comm is a NextGen program that is already in use in some airports (NextGen Data Communications, 2017). The system is used to supplement audio communication with digital text messages; for example, it is currently used in towers to send clearance instructions to pilots and could be used in ARTCCs to send rerouting instructions. At this time, Data Comm is not used to transmit PIREPs; however, the FAA plans to include advisory messages in Data Comm's future capabilities. Conceptually, PIREP information could be included in the advisory message data set.

4.1 NextGen Human Factors Recommendations

Findings from the E-IDS shortfall analysis are relevant to the problems identified with the PIREPs system as well.

E-IDS promises to make information up-to-date and easy to change as well as access.

A common system would ensure that PIREPs are standardized to the extent possible, while allowing for some flexibility from facility to facility.

E-IDS should address our specific guidance pertaining to the automatic delivery of PIREPs from one single point of entry to all required users. We recommend further study to clearly define how E-IDS would allocate PIREPs to individual controllers and other users. For example, perhaps the system could automatically distribute PIREPs based on areas affected by defined weather phenomena. In other words, instead of relying on the user to select positions and facilities affected by the weather conditions, the user would instead define the weather conditions within the system, which would then automatically disseminate the PIREP to the appropriate users. This could eliminate the step currently needed for the controller or facility manager to determine which positions/users are affected by every PIREP.

To improve ease of use, we recommend that this include sorting and filtering options, at least on the level of what is currently available in ERAM. E-IDS also promises improved display options, such as the integration of PIREPs with digital maps so that controllers can, for example, overlay the PIREP information on their graphical display. We recommend that this feature include options for toggling the information on and off, and adjusting the size and exact location of the PIREP content. Although not specifically addressed in the E-IDS documentation, we recommend the addition of the capability to convert abbreviations and codes into plain text. This could be accomplished as a mode setting (code versus plain text) or by providing an instantaneous means to convert or display codes that may be unfamiliar to the users.

Figure 14 shows a screenshot of the current Data Comm interface, which is notable in that most of the controllers' workflow consists of the large text-entry box. Text entry is necessary because of the large number of possible instructions and fixes that a controller may need to communicate. E-IDS could instead provide an option to forward a PIREP from its interface to an aircraft via Data Comm. For example, an en route controller using the PIREP interface in ERAM (see Figure 8) could right-click or double-click on a NOTAM to generate a drop-down menu with the option to "send via Data Comm," then enter the appropriate aircraft number or select it from a list. The controller could also have the option to select multiple PIREPs and send them simultaneously to multiple aircraft. Data Comm should provide the same benefits to PIREPs as it does to clearances in regard to reduced human error (e.g., misspeaking or poor audio quality) and quicker pilot compliance (e.g., the pilot presses a button giving acknowledgement rather than giving a verbal affirmation or read-back).

Figure 14. Data Comm interface. From NextGen Data Communications, 2017.

Alternatively, if PIREPs could be input directly from the aircraft via Data Comm, then this would shift the responsibility of PIREP data entry to the cockpit. PIREPs could then be linked to specific points in space and automatically disseminated to other users of NAS (e.g., aircraft, controllers, and weather specialists) simultaneously. This represents a significant shift from current PIREP procedures and would require further research and study to determine feasibility and potential means of implementation.

5. Conclusion

This document provides a summary of current PIREP use and some general human factors guidelines that may improve the user experience. Although there are some differences between the en route and terminal environment displays for PIREPs, there is a great deal of overlap of the human factors issues and recommendations for each.

The recommendations are summarized as follows:

- Single-point data entry.
  - Reduce the number of times the same data must be entered into the system.
- Ensure accessibility.
  - Data dissemination to all users should be automatic after the point of data entry.
  - Data dissemination to all users should be simultaneous.
- Be consistent.
  - Information should be displayed in a consistent manner across display types.
  - Eliminate multiple IDS programs by replacing them with a single common IDS program that will apply to maintenance procedures and training across the different domains.
- Improve search and display capabilities.
  - PIREPs should be organized for access at a glance.
  - PIREPs should be organized together without the need to navigate through multiple pages or scroll through superfluous or disparate types of information.
  - Organize PIREPs by time and relevance with regard to geographic area, altitude, or other relevant parameters.
- Display status information for PIREPs.
  - Allow notification of new PIREPs.
  - Provide an indication that a PIREP solicitation is due.
  - Automatically delete outdated reports to reduce the amount of unnecessary information contained within the system.
- Consider graphical representation of PIREP location and information.
  - PIREPs presented on a graphical display, similar to the displays available for pilot users on the FAA’s NOTAM site and the Aviation Weather Center’s PIREP site, may allow controllers to quickly evaluate if relevant PIREPs are available for specific areas.
- Provide contraction decoding capability or plain language format.
  - Provide a function that would quickly convert PIREP abbreviations to plain language for easier readability.

These recommendations should be considered to improve the usability and efficiency of the use of PIREPs for future systems. We stress the importance of specific human factors exercises, such as structured interviews, user workshops, or prototype mockups to provide specific user input to identify, develop, and validate system improvements

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ACRONYMS

ACE	ASOS Controller Equipment
ACE-IDS	ACE-Integrated Display System
AIRMET	Airmen’s Meteorological Advisory
AIS-R	Aeronautical Information System Replacement
ARTCC	Air Route Traffic Control Centers
ASOS	Automated Surface Observing System
ATC	Air traffic control
ATCT	Air Traffic Control Tower
AWOS	Automated Weather Observing System
CWAS	Center Weather Advisories
CWSU	Center Weather Service Unit
Data Comm	Data Communications
EDST	ERAM Decision Support Tool
E-IDS	Enterprise Information Display System
ERAM	En Route Automation Modernization
ERIDS	En Route Information Display System
FD	Flight Data
FLM/CIC	Front Line Manager/Controller In Charge
FSS	Flight Services Stations
GI	General information
IDS	Information Display System
IFR	Instrument flight rules
METAR	Meteorological Aerodrome Report
NAS	National Airspace System
NextGen	Next Generation
NIDS	NAS Information Display System
NOTAM	Notices to airmen
PIREP	Pilot report
RA	Radar associate
SAIDS	Systems Atlanta-Information Display System
SIGMET	Significant Meteorological Advisory
SOP	Standard operating procedures
SWIM	System Wide Information Management
TMC	Traffic Management Coordinator
TRACON	Terminal Radar Approach Control

Appendix A

The following is a list of the some of the data inputs or services accessible via the current information display systems available to terminal controllers. Note that services on the list may not be input automatically; as is the case with NOTAMs, the service may need to be accessed on a separate system and then entered into the IDS.

Runway Visual Range (RVR)

Digital Altimeter Setting Indicator (DASI)

Low Level Windshear Alert System (LLWAS)

Automated Surface Observing System (ASOS)

Flight Data Input/Output (FDIO)

Notices to Airmen (NOTAM)

Significant Meteorological Information (SIGMET)

Automation of Field Operations and Services (AFOS)

Meteorological Aerodrome Report (METAR)

Instrument Landing System (ILS)

Terminal Doppler Weather Radar (TDWR)

Air Force Airfield Automation System (AFAS)

Army Airfield Automation System (AAAS)

Advanced Weather Interactive Processing Stream (AWIPS)

Weather Systems Processor (WSP)

System Wide Information Management (SWIM)

Automated Weather Observing System (AWOS)

Automated Weather Sensor System (AWSS)

NAS Aeronautical Information Management Enterprise System (NAIMES)

Ribbon Display Terminal (RBDT)

Stand Alone Weather Sensors (SAWS)

Weather and Radar Processor (WARP)

Wind Measuring Equipment (WME)

Wake Turbulence Mitigation for Departures (WTMD)

Automation of Field Operations and Services (AFOS)

Integrated Terminal Weather System (ITWS)

Appendix B

Question List for Site Visit Interviews

NOTAMs

- What do you not like about the current system?
- Can you think of any constraints that would limit changes/updates to the system?
- What goal would you like for any system changes (e.g., speed, efficiency, capacity)?
- Is there any automation you would like to have/see? What would it buy you?
- Do you have any “outside-the-box” thoughts on how to handle NOTAMs?
- How much flight plan information should be integrated?
- Are you able to identify any NOTAMs efficiently and accurately (both newly issued or existing) that is pertinent to a given aircraft? Why or why not?
- If not, what prevents you from doing so, or what would assist you in identifying pertinent information more effectively?
- Does the current equipment help you comply with your NOTAM requirements per the 7110.65, 7210.3, or other orders (e.g., facility SOPs/LOAs)? Why or why not?
- Are there types/categories/limits to NOTAMs that you would explicitly NOT want to receive or be notified of?

PIREPs

- What do you not like about the current system?
- Can you think of any constraints that would limit changes/updates to the system?
- What goal would you like for any system changes (e.g., speed, efficiency, capacity)?
- Is there any automation you would like to have/see? What would it buy you?
- Do you have any “outside-the-box” thoughts on how to handle PIREPs?
- How much flight plan information should be integrated?
- Are you able to efficiently and accurately identify any PIREP (both newly issued or existing) that is pertinent to a given aircraft? Why or why not?
- If not, what prevents you from doing so, or what would assist you in identifying pertinent information more effectively?
- Does the current equipment help you comply with your PIREP requirements per the 7110.65, 7210.3, or other orders (e.g., facility SOPs/LOAs)? Why or why not?
- Are there types/categories/limits to PIREPs that you would explicitly NOT want to receive or be notified of?