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Guidance for the Display of Notices to Airmen (NOTAMs) on Information Display Systems

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16. Abstract

Notices to Airmen (NOTAMs) are a critical part of safety in the National Airspace System. They ensure that air traffic controllers are aware of temporary or new changes to the airspace that have not yet been published in the standard charts available to controllers and pilots. For example, NOTAMs allow controllers to safely move pilots around temporary flight restriction areas and make sure that they do not attempt to land at a runway undergoing construction.

Given the importance of NOTAMs and the constant need for controllers to manage traffic, it is critical that NOTAMs be delivered to controllers in a timely, efficient manner. This document provides a summary of the terminal and en route NOTAM delivery systems, their human factors pros and cons, and guidance as to how to improve the procedures and display systems involved. We also provide suggestions as to how this guidance might and should be implemented in 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 Philadelphia airport.

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Executive Summary

Notices to Airmen (NOTAMs) are a critical part of safety in the National Airspace System. They ensure that air traffic controllers are aware of temporary or new changes to the airspace that have not yet been published in the standard charts available to controllers and pilots. For example, NOTAMs allow controllers to safely move pilots around temporary flight-restriction areas and to make sure that they do not attempt to land at a runway undergoing construction.

Given the importance of NOTAMs and the constant need for controllers to manage traffic, it is critical that NOTAMs be delivered to controllers in a timely, efficient manner. However, from a human factors standpoint, there are a number of ways in which the current system could be improved. The delivery of NOTAMs from the NOTAM Distribution System to terminal controllers, for example, requires a large amount of manual intervention, leaving it vulnerable to delayed delivery, missed information, and typographical errors. The en route system is better in this regard, but all of the information display systems currently in use suffer from other human factors issues, such as poor search functions, a lack of user customization, and potential confusion due to the standard NOTAM display format.

This document provides a summary of the terminal and en route NOTAM delivery systems, their human factors pros and cons, and guidance as to how to improve the procedures and display systems involved. We also provide suggestions as to how this guidance might and should be implemented in 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 Philadelphia airport.

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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). Aeronautical Information Services (AIS) is the government source for collecting, validating, storing, maintaining, and disseminating aeronautical data for the United States, which provides the foundation for flight in the NAS. The AIS has many sources of information available to the users in the form of charts and publications. Examples are:

- Sectional charts – contain features such as prominent landmarks, roads, navigational aids, special use areas, and obstructions used primarily by visual flight rules (VFR) pilots
- Instrument flight rules (IFR) charts – contain such features as airports with an instrument approach, victor routes/jet routes with associated route data, special-use areas, navigation aids, and frequencies
- Airport/facility directories – contain the directories of all open-to-the-public airports with airport sketches, navigational aids (NAVAIDs), communications data, weather data sources, hours of operation, fuel, and services available
- U.S. Terminal Procedures – contain instrument approach procedure (IAP) charts, departure procedure (DP) charts, Standard Terminal Arrival Routes (STAR) charts, Charted Visual Flight Procedure (CVFP) charts, and airport diagrams

These charts and publications are all published on a regularly scheduled timetable from every 6 months (e.g., sectional charts) to every 56 days (e.g., IFR charts and Terminal Procedures). Changes that occur after the cutoff date for publication must still be presented to users and are done so through the use of Notices to Airmen (NOTAMs).

This document describes how NOTAMs are relayed to and used by air traffic controllers from a human factors standpoint. The controllers' primary tasks are communicating with pilots and moving them safely through the NAS; their time for accessing and interpreting extra information like NOTAMs is at a premium. Efficient and rapid consumption and transmission of NOTAMs from controller to pilot are important. In particular, this document will describe how NOTAMs are currently transmitted and displayed to controllers, how they should be transmitted and displayed according to human factors best practices, and how these suggestions might be implemented in future system updates (e.g., Enterprise Information Display System [E-IDS] and in agreement with various NextGen systems). The human factors guidance is supplemented with interviews conducted with current air traffic controllers and managers.

2. THE CURRENT NOTAM SYSTEM

NOTAMs originate from various sources, including airport managers, air traffic control facilities, technical operations services, and flight service stations, but they are all processed through the United States NOTAM System (USNS) for distribution through the NOTAM Distribution System (NDS). They are issued for many reasons, such as closed runways or airports, inoperative navigation aids, changes to published IAPs, and frequency changes. NOTAMs may be issued for temporary conditions, such as the passage of flocks of birds, flight restrictions due to special events (e.g., airshows

or rocket launches), and snow-removal operations; or they may be permanent changes, as in decommissioned very high-frequency (VHF) Omnidirectional Ranges (VORs) or changes in airway altitudes that are awaiting publication in the appropriate charts and publications. The procedures for creating and distributing NOTAMs are covered by Order JO 7930.2P – NOTAM.

Ideally, the Information Display System (IDS) will have relevant NOTAMs easily and readily accessible for the controller when the NOTAMs are needed; the system will mitigate missed NOTAMs or delayed access. A current difficulty with the NOTAM system is that there is a variety of information displays in use across different facilities, and as such, there is not necessarily a uniform manner for NOTAMs to reach any given controller.

2.1 How NOTAMs Are Transmitted to Controllers

Air traffic controllers generally receive NOTAMs at three different time points. There is typically a pre-shift meeting at which controllers receive a broad overview of the condition of the NAS, or at least the portion handled by their facility. This briefing would include relevant NOTAMs. Following the pre-shift meeting would be a sector or position-specific briefing, which would again cover relevant NOTAMs. This briefing would be more directly relevant to each particular controller and may discuss the NOTAMs in more depth (e.g., plans for responding to the NOTAM). Finally, new NOTAMs are delivered to controllers during the shift. Controllers are notified of a new NOTAM, as described in the following sections.

2.1.1 Terminal Controllers

There are 476 Airport Traffic Control Towers (ATCT) and 197 Terminal Radio Approach Control (TRACON) facilities in the US. Most facilities have one of four IDS that are currently in use today:

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

Appendix A contains a list of services or features accessible via these IDS.

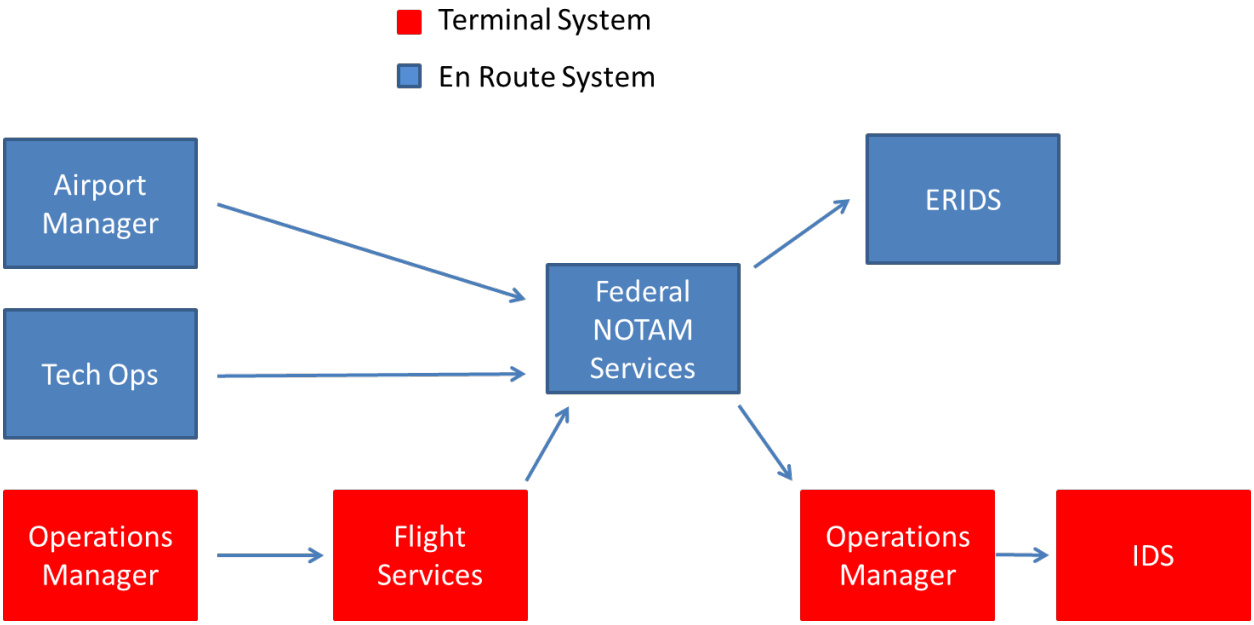
2.1.1.1 Terminal Summary

The four systems have much in common in the way information is received and displayed to the controller. The controller has limited control over the selection of information. Most information, such as which airport they may receive current weather information from, has been preselected by the facility's system administrators.

Despite the ability for some of the information displays to interact with outside systems, many are closed to sources like the Internet because of security concerns. They do not communicate automatically with the NOTAM service. Instead, personnel within the facility will search for NOTAM information on the FAA NOTAM Search website (https://pilotweb.nas.faa.gov/PilotWeb/), select what is pertinent to the controller, and manually type the information in the IDS. This method adds to

workload and is subject to issues associated with manual checking and entry, such as information delay, selection errors, missed information errors, typographical errors, etc.

The typical flow of information for NOTAMs in the terminal environment is depicted in Figure 1. Figures 2, 3, and 4 show examples of the screens used, in order, to deliver a NOTAM to a front-line controller. The Operations Manager or Front Line Manager in Charge (OM/FLMIC) will search the Federal NOTAMs Service online (see Figure 2). If the facility happens to have generated the NOTAM, it will be distributed to the NOTAM Service by the Automated Flight Service Station, and other facilities will then access it via the Service. The OM/FLMIC will decide which NOTAMs are relevant and then enter them manually into a text box in the IDS (Figure 3). Controllers will then be able to see these NOTAMs from their positions (see Figures 3 and 4).



Note: Red boxes indicate terminal-specific nodes, and blue boxes indicate en route-specific nodes. NOTAMs are generated by a position on the left of the diagram, are sent to the NOTAM service, and are then distributed to controllers to the right via IDS.

Figure 1. NOTAMs information flow

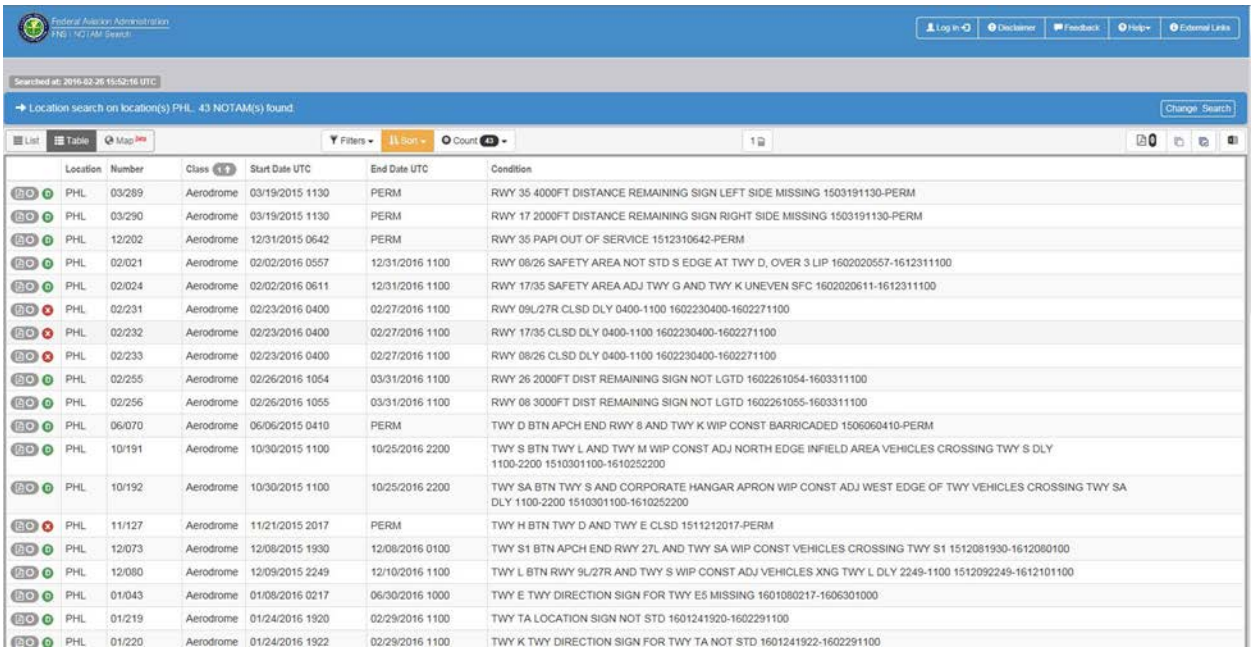
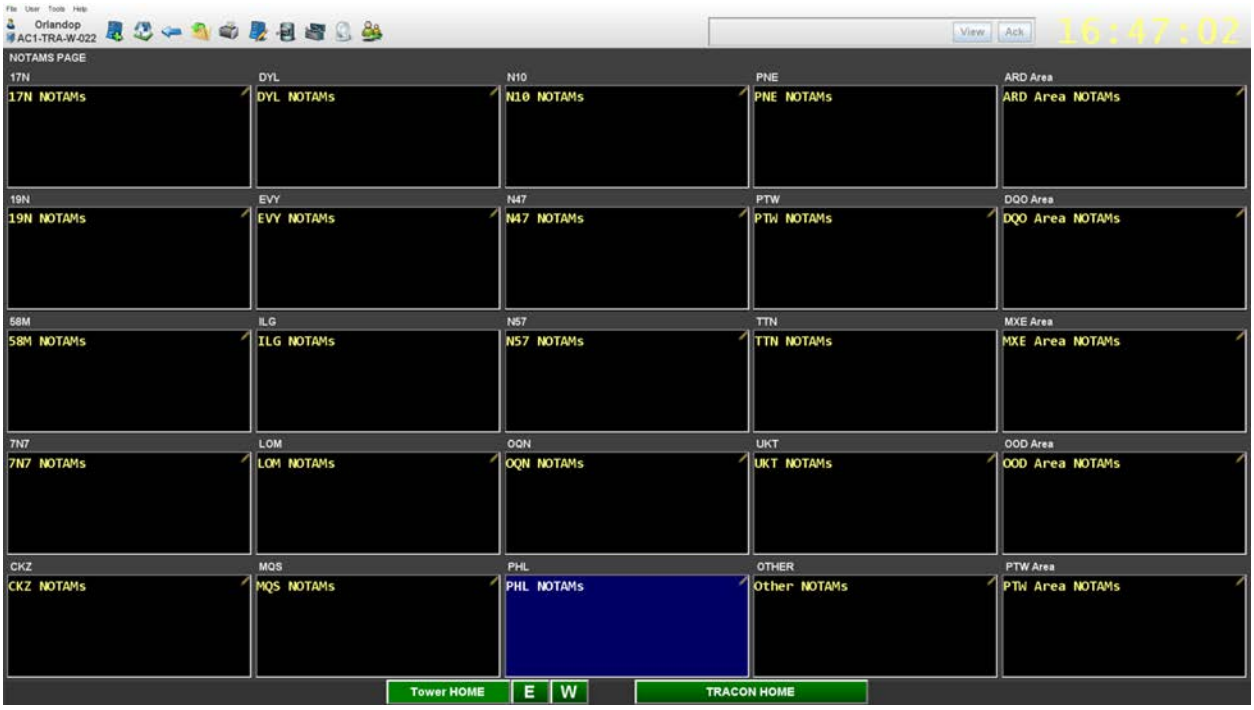
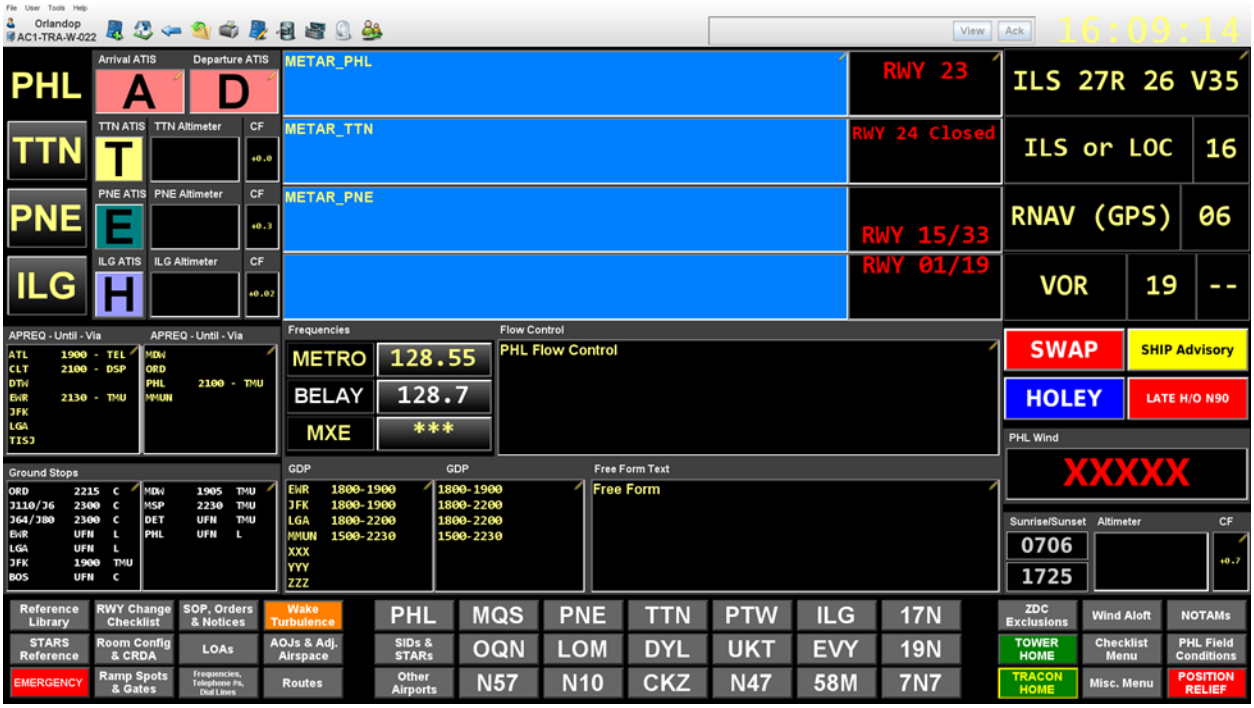


Figure 2. A screenshot of Philadelphia airport NOTAMs search via Federal NOTAM Service web page.



Note: Each box is designated for a different airport/area. Here, Philadelphia has been selected (highlighted in blue). The OM can edit each box to manually enter relevant NOTAMs from the Federal NOTAM Service. Controllers can access a list of NOTAMs by selecting a box.

Figure 3. A screenshot of the NIDS NOTAMs display



Note: NOTAMs can be accessed by selecting the NOTAMs box in the lower-right corner of the menu (two boxes above the red 'position relief' button), which takes the user to the screen in Figure 3.

Figure 4. A screenshot of the NIDS display that a controller would see at her position

2.1.2 En Route Controllers

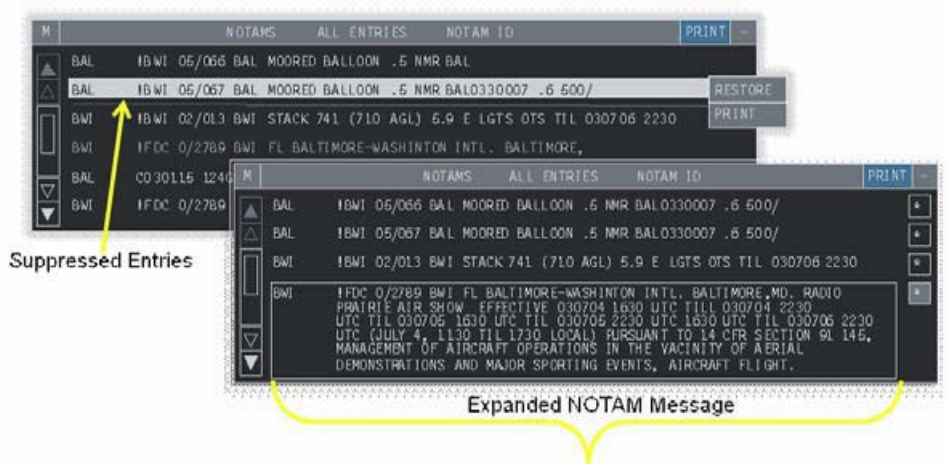
En route controllers have two ways to access NOTAMs: the Radar Associate (RA) position can access NOTAMs at their position via the typical En Route Automation Modernization (ERAM) interface, or either position (RA or Radar, R) can access them via the additional En Route Information Display System (ERIDS) interface.

2.1.2.1 En Route Automation Modernization

ERAM makes NOTAMs available via a tab on the main screen at the RA position (see Figure 5). The tab both opens and closes the NOTAM view (see Figure 6), which opens to a default but customizable location on the screen.

Note: Note the 'NOT' tab at the top center of the screen for accessing NOTAMs.

Figure 5. ERAM display at RA position



Note: Figure from TI 6110.101, the ERAM Air Traffic Management (ATM) user manual.

Figure 6. NOTAM menu within ERAM

2.1.2.2 En Route Information Display System

ERIDS (see Figure 7) 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, Air Traffic Control (ATC) procedures, sector binder information, pilot reports (PIREPs), and NOTAMs. As opposed to the terminal environment, ERIDS allows for automatic distribution of NOTAMs because it is able to access information over the Internet (Figure 2). There may still be some intervention in the system, for example by a manager setting certain filters (see Figure 8), but ERIDS provides a much more automated NOTAM system than SAIDS or NIDS.

Figure 7. ERIDS console on moveable arm between R and RA positions

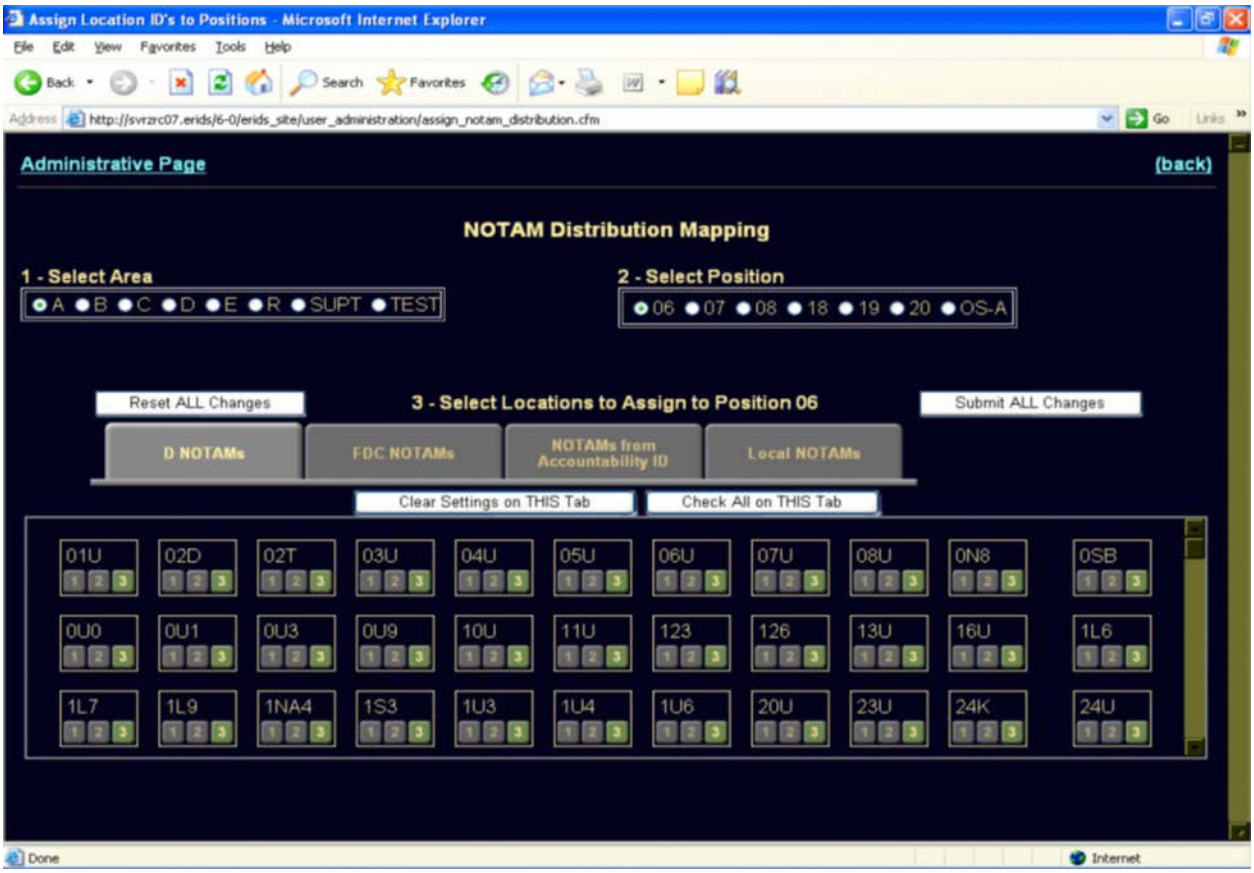


Figure 8. NOTAM Distribution mapping menu for an ERIDS-equipped facility

2.2 How NOTAMs Are Used by Controllers

A controller will review critical information, such as NOTAMs, weather (current and forecast), traffic-management initiatives, and airport conditions, many times during each shift of duty. A controller will review these items at the beginning of her shift preceding assignment to any operational position, during the position relief briefing prior to accepting responsibility for an operational position, and prior to issuing an approach clearance or en route descent to an arrival aircraft. The review of this information at the beginning of the shift will generally take place away from the control positions and may be in written form in a read/initial binder; however, the review of NOTAMs during the position relief briefing and prior to issuance of an approach clearance will be done using the facility's IDS. More so for en route controllers, the information reviewed during the beginning of the shift and position relief briefing will normally cover a large geographical area whereas the NOTAMs review for an arrival aircraft will concentrate on the approach used and the landing airport.

2.2.1 Terminal Controllers

The systems available to terminal controllers do not allow for much interactivity with NOTAMs. As such, controllers will simply monitor their IDS for NOTAMs as appropriate or perhaps be informed of one directly by a supervisor. This straightforward state of affairs can be contrasted to the options that ERIDS affords en route controllers.

2.2.2 En Route Controllers

En route controllers have access to NOTAMs through ERAM (at the RA position) or ERIDS. Because there are thousands of NOTAMs published daily, NOTAMs follow a set format (specified in JO 7930.2P), which allows for filtering and sorting. Among the many required elements for NOTAMs are a location identifier of the affected facility, keywords, and an effective/expiration time. ERAM and ERIDS both allow for some amount of sorting and filtering; these two systems are described in more detail in the sections below.

2.2.2.1 ERAM

The description of the ERAM NOTAM system in this section is adapted from the RA position user manual (TI 6110.101).

When a NOTAM is added to the system, the tab (or the view, if open) displays a notification. If there are no data to populate the view, it consists of the header only. The NOTAMs view (see Figure 6) 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 NOTAMs view menu LINES option. Scroll bars are located on the left-hand side of the view and allow the user to page up/down or scroll a single line at a time. Figure 6 shows the NOTAMs view with suppressed entries and with an expanded entry displaying the complete text for a single NOTAM.

Complete text for a NOTAM entry may be displayed via the NOTAM entry pick area (i.e., an asterisk within a square box). Each NOTAM entry that exceeds 80 text characters is truncated and an additional information indicator (*) is provided at the end of the entry to indicate that more text is eligible for display. When the additional information indicator is active, the background color of the indicator turns gray. A scroll bar is displayed when the number of lines exceeds the number specified in the NOTAM view menu LINES option.

When a NOTAM message is expanded, the view size expands, as needed, up to the value associated with the LINES setting. To display the full message, the other NOTAM entries are pushed downwards or upwards. If the LINES value is less than the number of lines associated with the expanded NOTAM entry, a scroll bar is provided to view the entire message. To contract an expanded NOTAM entry, the user selects the * pick area again, thus acting as a toggle. As the entry is contracted, the view size may change if the number of lines is less than the LINES setting. Those NOTAM entries are redisplayed if there were previously displayed eligible entries that were pushed downwards or upwards, such that the entries were hidden from view.

Following the cancellation or expiration of a NOTAM entry, the text will be gray. This is called cancellation coding. The gray text coding associated with the expiration and the cancellation of a NOTAM entry indicates that an entry will automatically be deleted by the system after an adapted amount of time. The cancellation coding will remain until the entry is deleted from the view. When an entry is coded for system removal, the user can still suppress/print or restore/print that entry.

The view header gives controllers the ability to sort and filter NOTAMs. The sort menu allows controllers to sort by cancelled time, effective time, expiration time, location ID, NOTAM ID, or NOTAM type. The filter drop-down menu allows for selection between all NOTAMs, NAVAID and approach NOTAMs, or NAVAID outages only.

2.2.2.2 ERIDS

NOTAM filtering is accomplished in two ways:

1. An ERIDS data manager specifies what information is presented for each sector within the facility (see Figures 8 and 9) through the distribution mapping panel.
2. The controller searches by location identifier and displays any NOTAM that is currently in the NDS (see Figures 10–14).

Figure 8 is an example of an ERIDS NOTAM distribution panel, which determines how NOTAMs are filtered within the facility. This panel allows the system administrator to arrange for automatic distribution of NOTAMs to any ERIDS position within the ARTCC by selecting each area and position individually. The system administrator then decides which NOTAMs will be sent to each position by location identifier and category of NOTAM.

Figure 9. Result of ERIDS NOTAMs search filtered for sector 4

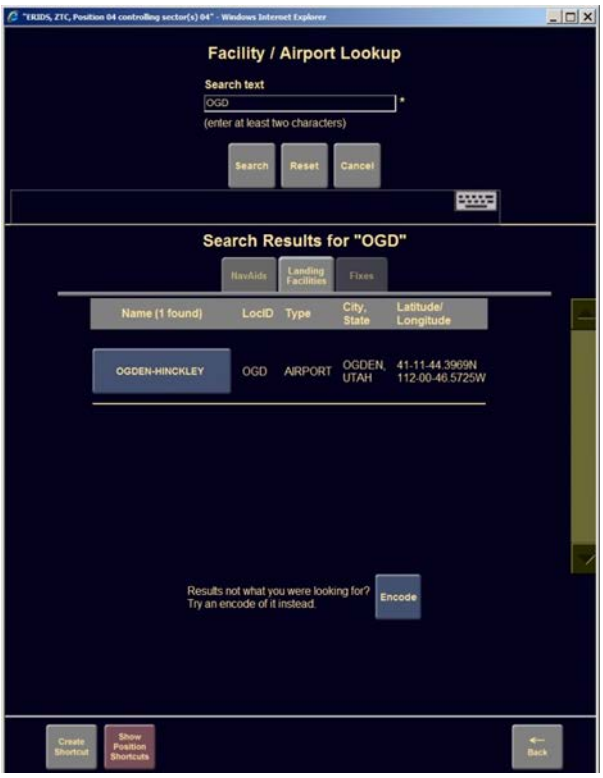


Figure 10. Controller using the Lookup feature for OGD airport

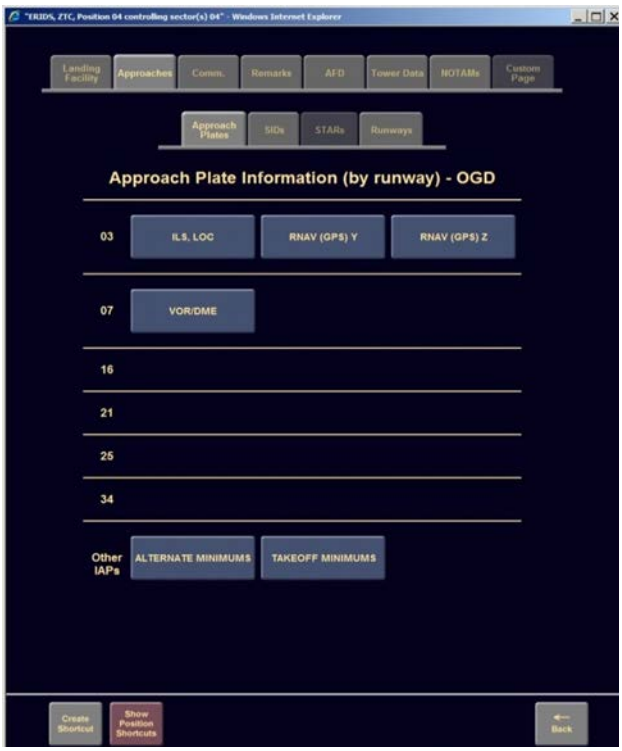


Figure 11. Page returned after selecting OGD airport

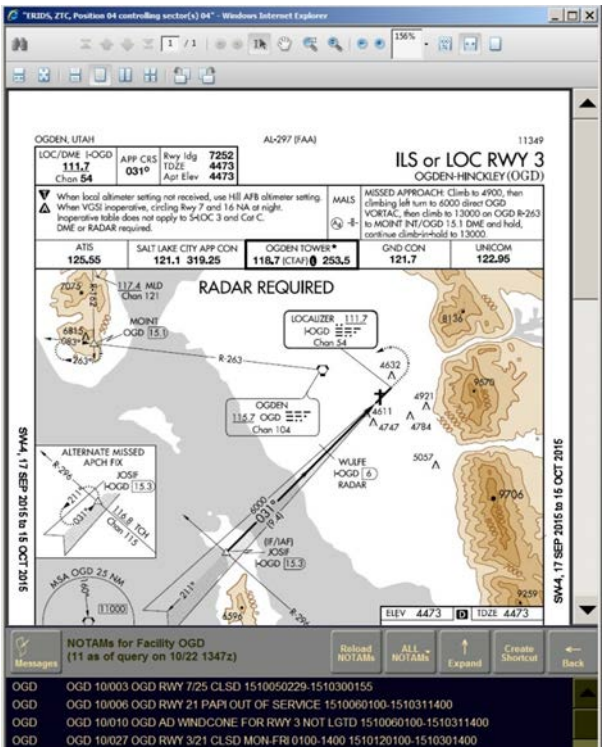


Figure 12. OGD approach plate for ILS or LOC RWY 3 selected with NOTAMs for only OGD displayed underneath

Figure 13 is an example of the NOTAM display during a position relief briefing. The NOTAMs shown in the figure provide information covering different areas and events, such as a military training route (instrument route), a Temporary Flight Restriction (TFR) due to firefighting activity, obstructions, and outages to different facilities. The text coloring in the example shows whether the NOTAM is in effect at the current time (yellow) or for a time in the future (blue), or if the NOTAM has expired or was cancelled (grey).

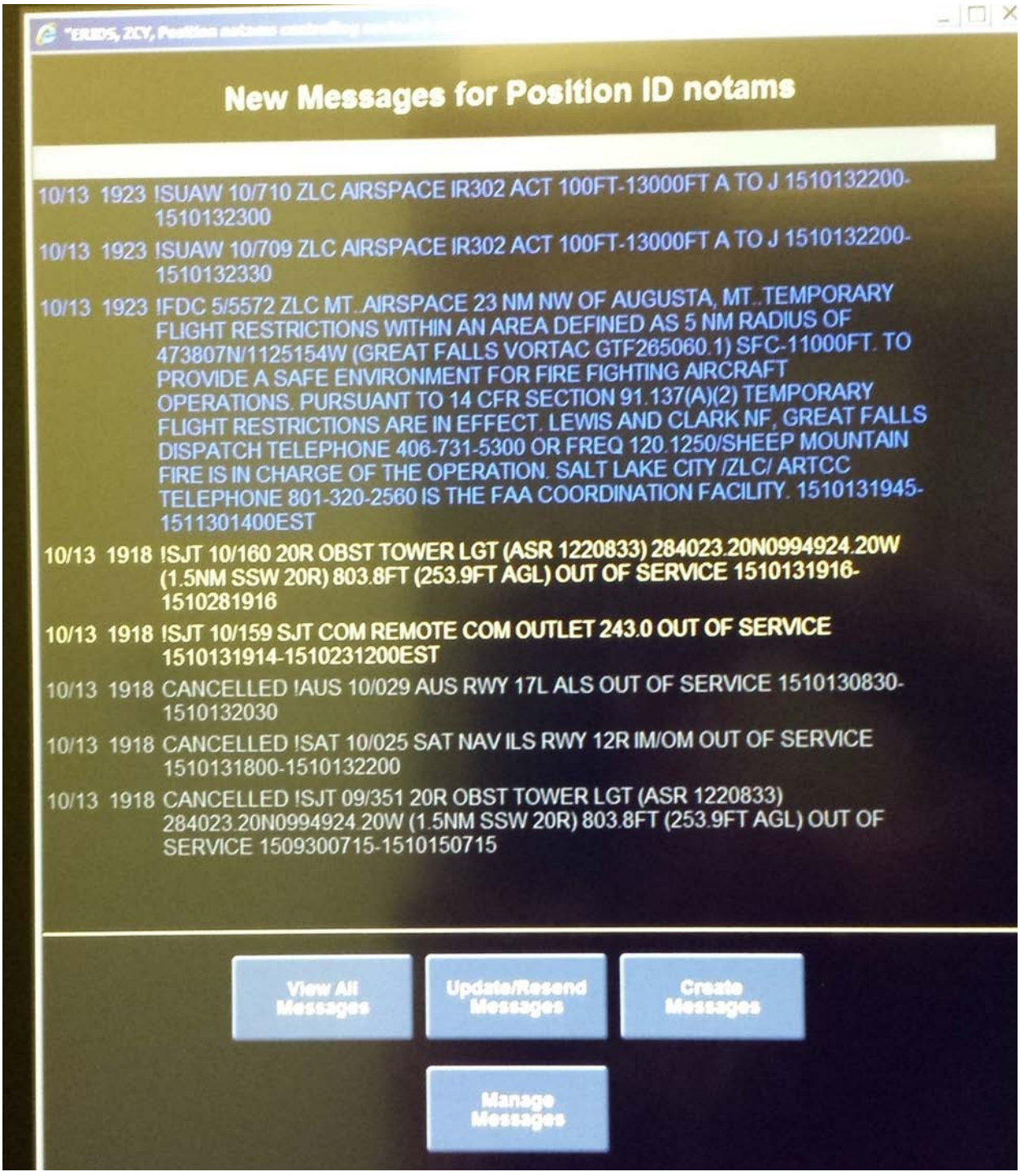


Figure 13. ERIDS display showing NOTAMS filtered by sector

Figure 14 is an example of the ERIDS display filtered by location in preparation to clear an aircraft for an Area Navigation (RNAV) approach to runway 31 (RWY31) at Atlantic City airport (ACY). Notice that the NOTAMs under the approach plate all have ACY listed as the location and contain hazards and changes to NAVAIDS, obstacles, and approaches to that airport.

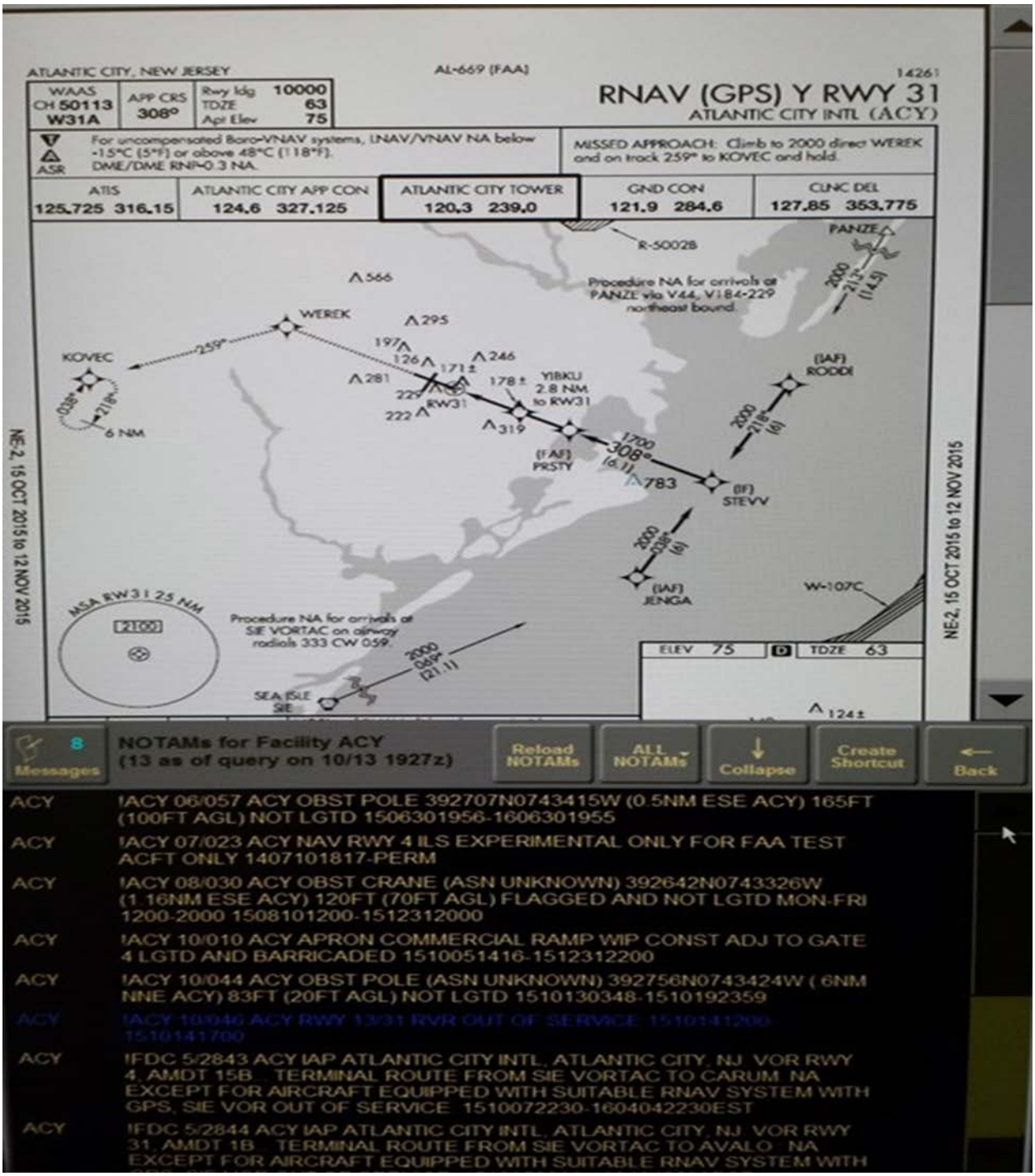


Figure 14. ERIDS display showing NOTAMs filtered by location – ACY

2.2.3 Usage Elements Common to Both Terminal and En Route Systems

Once NOTAMs have been accessed by a controller, their use is similar regardless of position. The controller must determine which NOTAMs are relevant to each pilot. For instance, a controller may decide not to relay a runway outage NOTAM to a pilot who will not be near the affected runway. If a NOTAM is relevant, however, the controller is required to relay the entire NOTAM to the pilot; no particular element or portion of the message is more or less important.

An incoming NOTAM does not often lead a controller to search for additional information. However, when looking at weather or other information (e.g., an approach plate or general airport description), controllers commonly search for any relevant NOTAMs. For example, an en route controller might consider directing a pilot to ACY and want to make sure there are no outages affecting this decision. Likewise, if a pilot requests an approach, such as shown in Figure 14, the terminal controller would want to make sure that this was feasible.

NOTAMs are, of course, a critical part of properly moving aircraft through the NAS. Many NOTAMs are important for controller decision-making because they involve obstructions or other issues that necessitate rerouting an aircraft. As a practical matter, however, this decision-making often occurs above the level of the frontline controller. For example, traffic-flow management or facility managers would make rerouting decisions for major events, such as air shows. Other decision-making is assigned as appropriate: A NOTAM that affects the approach phase would be addressed by an approach controller, whereas a NOTAM that affects a runway would be addressed by a tower controller. This arrangement can occasionally lead to perhaps undesirable outcomes, such as an aircraft needing to perform a U-turn or turning approach instead of coming straight in if the approach and tower controllers have conflicting priorities.

2.3 Pros and Cons of Current System

2.3.1 Terminal Environment

We are not aware of any studies that have specifically examined the use of NOTAMs in the terminal environment, or research on the effectiveness of the various information displays used across facilities (such as the Sollenberger et al. study discussed in section 2.3.2 for the en route environment). Given the description of NOTAM use so far and further discussion of human factors issues in section 3, however, we will describe some specific benefits and downsides to the systems currently in use.

Compared with the pre-information display world of printed manuals, any of the information displays available in terminal facilities should provide a benefit. This benefit was verified for the en route environment, as described in section 2.3.2, but presumably the SAIDS, ACE-IDS, and NIDS systems also quicken controllers' access to NOTAMs and other information by making it all available in one place. Even if the interfaces were difficult to use or simply could be improved, they should be better than needing to find the piece of paper that a NOTAM was written on or asking a manager to repeat it again (e.g., Sollenberger et al., discussed in section 2.3.2).

In contrast to ERAM or ERIDS, the information displays available to terminal controllers do not allow for much interaction in terms of sorting or filtering by the frontline controller. Although there

is value in letting someone else (e.g., a manager) take the time to perform these actions to better allow the controller to focus on traffic management, there is also value in giving the controller more control over her information flow.

Although the terminal information displays technically allow for more automated access to outside sources such as NOTAMs, practically speaking, they are usually not granted such access for security reasons. This forces someone (typically a manager) to manually obtain information on one computer and then type it into the information display so that it can propagate to the controllers. This allows for human error to enter the system because the manager may produce a typo, allot the NOTAM to an incorrect sector, or become busy and not see an important NOTAM in a timely manner. Allowing more automation into the IDS would avoid these issues.

2.3.2 En Route Environment

Sollenberger, Koros, and Hale (2008) performed a study to compare controller use of ERIDS to the previous information access process, which was looking in printed manuals. Although NOTAMs were not specifically studied, some of the results are generalizable. On the principle issue of usability, controllers found information in ERIDS and in paper manuals in approximately the same amount of time. However, it must be noted that this is likely due at least in part to the researchers making the manuals available nearby; when they looked for the manuals in the actual work environment, the researchers found that they were typically not well-organized or even all in one place. Thus, searching through paper manuals would take longer than ERIDS when accounting for the need to find the manual in the first place. This conclusion is supported by the finding that controllers rated the time to access various types of information as uniformly faster using ERIDS than searching in manuals. The controllers also rated the ease of getting information as higher using ERIDS, and rated ERIDS as generally being associated with a lower workload. Overall, controllers in the field preferred ERIDS to printed manuals. The benefits of ERIDS are such that controllers said that they accessed information on it more often than they would via printed manuals; the relative ease of using ERIDS allows them to look up information themselves as opposed to asking a manager to look it up and report back to them.

Although the ERIDS system offers many desirable features, it could be improved. For most different types of information, controllers searched ERIDS as if it were a printed manual by using links from a table of contents or index, as opposed to using the ERIDS search tool. Sollenberger et al. note that this could be a training issue, but it could also be due to poor search design, particularly in the display of results.

There are also improvements more specific to NOTAMs that could be suggested from a human factors standpoint. For example, additional filtering and sorting over what is currently available may be useful. Looking at the results in Figure 14, NOTAMs are sorted numerically by NOTAM number; the search first lists an obstruction notice, then a NAVAID notice, then back to an obstruction notice. This arrangement is not an order that allows users to locate information quickly. Instead, NOTAMs should be grouped by type, keyword, or perhaps effective time. This kind of sorting is available in ERAM.

In addition to the lack of sorting options, controllers are also unable to do any filtering on search results, which could be useful. Continuing with the example in Figure 14, the controller began by searching for information for ACY airport, then narrowed the request to the RNAV (GPS) Y RWY31 approach. This search displayed the IAP along with all the NOTAMs for ACY. However, none of the eight NOTAMs displayed would be required to be relayed to the pilot on this approach (in accordance

with JO 7110.65 – ATC). Specifically, three of the eight NOTAMs are for obstructions, which would not have to be relayed if the aircraft is on an instrument approach; two apply to a VOR approach, which the aircraft is not on; one is for the RWY 4 ILS approach, which the aircraft is not on; one is for construction on the airport; the final one might apply but is not effective for another 16 hours (current time 1927Z, effective time 1200Z the next day). Filtering options, such as for an aircraft's specific approach, could further reduce the demands placed on the controller. Note that this level of specification is not present in ERAM or ERIDS. Research may be necessary to determine if the benefits of more specific filtering might be offset by the downside of backtracking/refreshing the system when the controller is finished relaying the current NOTAM results (e.g., moving back from the RNAV approach to ACY in general and perhaps proceeding on to a different approach plate).

3. HUMAN FACTORS BEST PRACTICES

3.1 Broad Guidelines

As can be seen from the description of currently used systems, there is a wide variety in the interfaces used by controllers and the manner in which information flows to them. Given the differences in information required across the ATC domains, some variety is to be expected and may be beneficial. However, there are still some general guidelines that can be provided from a human factors viewpoint that apply to any IDS and that provide suggestions for how the systems should differ.

A good overview of human factors guidelines for information displays is provided by Yuditsky, Friedman-Berg, and Smith (2004). This document includes specific reference to some, but not all, relevant guidelines provided by the Human Factors Standard (HF-STD-001; Ahlstrom & Longo, 2003). The work of Yuditsky et. al. included information provided by controllers across domains, which inform what particular aspects of current IDS are most in need of correction. We will highlight some of the main results from that study here.

The first general guideline of Yuditsky et. al. is that information must be accessible. Accessibility refers both to the "real world" and within an IDS. For example, flight services stations (FSS) typically have only one or two displays available for all controllers to share; if they are in use, another controller physically cannot access information. Even if an IDS is physically available, information could be difficult to access because of poor organizational structure or interfaces (such as described in Sollenberger et al. 2008). Yuditsky et al. report that many controllers consider their IDS to be overly cluttered/have counterintuitive menus; this poor organization makes it difficult to find information in an efficient manner. Once information has been found, it can also be poorly organized, as in the example of the NOTAMs in Figure 14. The information itself could also be difficult to use, such as a PDF document without a search feature. If controllers need to scroll through pages of text to get to the information they want, that information is not as accessible as it should be.

The second guideline is that information should be current, and how current should be apparent to the controller. This point is fairly straightforward.

The third guideline is that information should be comprehensive. Yuditsky et al. again use the FSS as an example, noting that because their IDS do not include all the information they would like to access, they find the IDS to be inefficient. The need to rely on several sources for information (e.g., an IDS and printed books) places a burden on the controller to remember what source has what kind of information and reduces efficiency simply by not having all of that information in one place. Information

should be both comprehensive and relevant. Controllers reported that updating their systems was typically a chore. This difficulty leads to some information not being entered into the IDS, leaving gaps. Conversely, the difficulty in updating also leads to out-of-date information remaining on the system and creating clutter. Clutter creates inefficiency by requiring the controllers to sort through information that they will never use to find what they are looking for. Adding and removing content from an IDS should be fairly simple to ensure the information is comprehensive, current, and easily accessible.

The fourth guideline is that system notifications should be appropriate to the controllers' needs. Yuditsky et al. report that although many information displays have notifications, they commonly occur when unnecessary (such as for a non-time-critical update), do not occur when necessary (when a relevant update does occur), and are frequently of the wrong level (such as blocking important portions of the screen or requiring a controller response for a relatively unimportant update). Notifications should be designed to take the controllers' time demands and attention into account. For example, a non-critical update could be noted visually when the controller accesses the relevant materials, whereas a critical update could be noted with an auditory signal and a pop-up on the IDS.

The fifth guideline is that systems should be standardized. Whereas different types of controllers may have different IDS needs (e.g., en route controllers commonly access different content than terminal controllers), standardized systems would still be beneficial in circumstances such as a facility emergency when controllers must change workplaces. As noted previously, terminals vary widely in the equipment used at different facilities. If a controller were to change jobs, she would have to undergo a period of training before using the new system, and presumably have a period of time even after training to overcome habits associated with the previous system. Conversely, if every facility uses a standardized system, then a controller could switch facilities with little difficulty.

Similarly, standardization simplifies controller training in general. Controllers could be trained to use each of the various information displays, or their training could be targeted to a single system with a resulting restriction in where they could work (e.g., only at facilities with SAIDS-4 if that is what they learned). Standardized systems would allow all trainees to learn a single system, work at any facility, and transfer between them with no need for retraining. Flexibility should be allowed so that controllers can customize their IDS to their particular needs.

3.2 Specific Suggestions

Beyond the general recommendations provided by Yuditsky et al., we provide more-specific recommendations for improvements to the NOTAMs system.

NOTAM input and distribution to frontline controllers should be completely automated. The NDS is an online tool from which ERIDS automatically pulls reports. In the terminal, however, a manager must manually copy NOTAMs from the NDS to their IDS. This procedure allows for the possibility of both human error (e.g., typos or omission of NOTAMs) and for NOTAM entry to be delayed if the manager is too busy to monitor the NDS. In either the terminal or en route environment, a manager then assigns NOTAMs to locations or to controllers. This process could likely be accomplished by an algorithm that uses the spatial information in the NOTAM (e.g., an airport or waypoint identifiers) to direct it to the appropriate controller station. However, it may be worthwhile to allow for some manager intervention to ensure that NOTAMs are directed to the correct controller. The algorithm could also automatically present and remove NOTAMs depending on their start and end time, and provide some of the sorting functions described earlier (e.g., grouping by type or time instead of

NOTAM number). Some of these functions are available in some systems (e.g., ERAM), but they should be applied universally.

Controllers should have access to all the NOTAMs that could potentially be relevant to them, but with the option to filter those NOTAMs in a variety of ways. NOTAMs are currently filtered to some degree, but this is performed by someone other than the frontline controller. This could result in the controller missing a relevant NOTAM or in some other mismatch between the controllers' desired workflow and the options available to them. However, the controllers' workload should not be overly burdened with information. An intelligent algorithm or the ability for each controller to customize their IDS as desired could find the proper balance between comprehensive information and clutter.

NOTAMs should be decoded into plain language. The FAA's policy for NOTAMs (JO 7930.2P) specifies how NOTAMs should be coded and transmitted, including rules for the order of the information in the message and what abbreviations should be used for various terms (e.g., RWY for runway). Although these rules are useful for standardizing the form of a NOTAM, they are not useful for the frontline controller who must read them. An example from JO 7930.2P reads "ABQ RWY 8/26 CLSD 1307040000-1307061200." Although these particular abbreviations are likely decipherable (Albuquerque, runway, and closed), not all of them are obvious, even to controllers. Additionally, the NOTAM can be reformatted to speed comprehension. The repetition of ABQ is unnecessary, for example, and the effective dates could be spelled out to speed comprehension and remove unnecessary information. Even longer NOTAMs, and especially those with unusual or infrequently seen content, would benefit from decoding before being read by the frontline controller. The controller needs to read the NOTAM and communicate the contents to pilots; both would benefit from a plain-language version of the message.

Although, to our knowledge, the plain-language expansion of NOTAMs has not been studied with controllers, it has been studied with pilots. Shocket, Stanfield, and Levy (1984) presented pilots with a flight report containing both weather reports and NOTAMs in either standard or expanded language. The pilots provided both objective and subjective data on the reports; they were tested for comprehension and reading time and gave their impressions of the two options. There were comprehension mistakes in all areas (four kinds of weather information and NOTAMs) with the most in NOTAMs. Notably, mistakes were dramatically reduced when the NOTAMs were expanded into plain language. Of the 34 pilots tested, 25 said that expanded NOTAMs would be desirable or very desirable, even though 28 said that they had moderate or better knowledge of NOTAM abbreviations before the study. Even though there was not a significant difference in the time taken to get through the briefing, pilots subjectively felt that the briefings went faster. Although the pilots in this study were not controllers, the responses were largely the same for pilots with high amounts of flight time. This study provides some evidence for the value of expanding some abbreviated information, such as NOTAMs, for controllers.

NOTAMs should be displayed graphically. Controllers perform their jobs spatially; they look at radar screens and maps, and create spatial representations of everything in their airspace now and where it will be in the future. NOTAMs are presented to controllers only as text and on a different screen than where all of their other spatial information is provided. This requires the controller to decode the NOTAM and attempt to mentally place it in the appropriate location, then determine if it affects any of the aircraft about which they are thinking at the moment. One way to reduce the controller's workload would be an option for controllers to display NOTAMs automatically on the radar screen when they are broadcasted, or shortly before they become effective. However, depending on the exact implementation,

this could be startling for controllers, and it is also likely that NOTAMs for airports would pile up if several affect the same location. A second option is to continue having NOTAMs appear on a second screen (such as the IDS) but with a clickable option to display the NOTAM on the radar screen. This would allow the controller to directly visualize what airspace is affected by the NOTAM, if desired. Another potential feature might include the option for the radar or the IDS to display details about the NOTAM next to its location, perhaps similar to a data block. Controllers should have personal customization options for the graphical display so that they are not surprised or have other information on their display unexpectedly blocked by the NOTAM. However, it would likely increase the efficiency of their work if NOTAMs could be explicitly placed in the appropriate part of their airspace.

The ERAM implementation of NOTAM display (see sections 2.1.2.1 and 2.2.2.1) provides some of this customization. For example, controllers can decide how many lines of results should be shown when the NOTAM tab is clicked, which controls how large the NOTAM box appears. The cancellation coding feature, which changes the font color of NOTAMs after their cancellation time, is also useful. Along with the ability to choose where the results box appears and the enhanced sorting options, these features should appear in any IDS available to controllers. These features should remain customizable and perhaps be subject to additional human factors testing; for example, some controllers could find the cancellation coding to be subtle and may desire a more salient change.

4. AIR TRAFFIC CONTROLLER INTERVIEWS

We conducted a site visit to interview controllers to confirm and potentially expand on the advice and information previously presented. Although we had a prepared list of questions (presented in Appendix B), the controllers were very forthcoming and eager, and the discussion was not strictly guided. The interviews largely confirmed the suggestions given above, but they are described in more detail in the following section.

4.1 Terminal Interview at KPHL

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. KPHL 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.

The controllers and OM confirmed the general procedures described in section 2.1.1. The OM checks for NOTAMs on the Aeronautical Information System Replacement; this is done once per shift or twice per day. The NOTAM list is printed out, and the manager notes any new and relevant NOTAMs. The manager then goes to another computer terminal to manually enter the NOTAMS into SAIDS-4. The decision of which NOTAMs to enter and how to do so is at the discretion of the OM; we observed NOTAMs entered in a variety of ways, ranging from standard International Civil Aviation Organization (ICAO) format to a fully decoded, plain-language sentence. The OM sometimes receives a call from Flight Services with a (typically important) NOTAM. Once the OM has entered a NOTAM in the system, it becomes available to controllers at their stations on SAIDS-4. The KPHL stations had been customized with a NOTAMs button, but controllers told us that there were several ways to get to a list of NOTAMs. Once NIDS goes online, they will again have a direct button to NOTAMs, as shown in Figure 4.

In regard to the current system, the controllers' and managers' complaints largely mirrored our suggestions for improvement. They did not like that the system was manual instead of automated; two of the controllers had previously worked in en route centers and greatly preferred the automation supported by ERIDS. They did not like the ICAO format for displaying NOTAMs and much preferred a plain-language version. The controllers noted that some elements of the NOTAM message, such as the NOTAM number, were irrelevant to them. The situation is doubly inefficient because they cannot sort or filter their NOTAM list, and it is currently sorted by NOTAM number. They also recommended that dates be in a separated or more easily understood format instead of the current YYMMDDZuluTime format, all altitudes be standardized to mean sea level, all locations be referred to via fixes and distances instead of latitude/longitude, and all NOTAMs have a clear cancellation time. With respect to the last point, the controllers had experiences in which NOTAMs conflicted because of a lack of cancellation time; in such a case, it is obviously difficult for the controller to know the proper action to take.

The controllers also noted an inefficiency when it comes to NAVAID or VOR-related NOTAMs. Because those types of NOTAMs are reported by Centers and NOTAMs are organized by the originating airport, these NOTAMs have to be accessed by going to a different section of the IDS, even though it affects the controllers' immediate sector.

Procedurally, the controllers were displeased with the requirement (e.g., JO 7110.10X) to communicate "pertinent" NOTAMs to pilots. They specifically did not like that they are left to make subjective determinations as to which NOTAMs are pertinent. The controllers would prefer that NOTAMs be denoted somehow to indicate their urgency or importance.

Looking to the future, the controllers (particularly the two with previous en route center experience) suggested that a short-term solution would be to equip ERIDS in the terminal environment. Long-term, they would like solutions to the problems mentioned above. They would specifically like an automated system that delivers intelligently sorted NOTAMs pertinent to their current task (e.g., at the level of a particular aircraft or airport) that can be accessed quickly and easily. The NOTAMs should be presented in an easy-to-read, plain-language format with only the information relevant to the controller (e.g., not the NOTAM number). At a high level, controllers want to have their eyes-on-scope time to be as high as possible. At a low level, controllers also expressed an interest in having standard QWERTY keyboards instead of the current ABC keyboards.

Overall, the interviews supported the findings from our research. The controllers did not generate suggestions with human factors in mind, but their suggestions for improvement were largely human-factors-related. A notable exception was the desire for a more objective definition of what NOTAMs are pertinent so that controllers do not feel as if they will be blamed if a subjective choice were to lead to an accident. The open-ended definition also leads to conflicts between different controllers or managers because they can disagree on if a particular NOTAM is pertinent or not.

5. LOOKING FORWARD: ENTERPRISE INFORMATION DISPLAY SYSTEM

The FAA is undergoing a huge modernization program (i.e., NextGen) to update many of its systems and procedures. Some of these programs, such as System Wide Information Management (SWIM), provide critical infrastructure that should benefit information flow to controllers. The E-IDS, for example, is proposed to replace all of 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). From the controllers' point of view, however, it is important to emphasize that the "how" of the system is not as critical as their means of accessing the information: Their need is for timely, accurate, easy-to-access NOTAMs, whether that is provided by SWIM or some other process. Thus, the discussion here will focus on E-IDS and briefly mention Data Communications (Data Comm) as the NextGen systems that provide information directly to the controller.

We are not aware of any prototypes for E-IDS, but there are some documents (Burke and Burnham, 2015; Burke, Wright, and Gill, 2015) that 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. Burke and Burnham (2015) estimate that the various improvements provided by E-IDS (e.g., automatic transmission of information, smoother workflow, 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 suggest benefits for managers in data-management tasks, such as updating charts, which should benefit front-line controllers by ensuring that data is 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 en route centers to send rerouting instructions. Because NOTAMs are already communicated in text form, Data Comm would provide another avenue for controllers to send them to pilots.

5.1 NextGen Human Factors Suggestions

As noted in section 3, the human factors benefits and problems of E-IDS cannot be evaluated without a prototype to evaluate. However, the description does appear to address all of the broad guidelines listed in section 3.1. E-IDS promises to make information up-to-date and easy to change and access. By relying on SWIM and being used in all facilities, E-IDS would also ensure that NOTAMs (and other information) are comprehensive and standardized.

In regard to the specific suggestions in section 3.2, E-IDS would address our procedural guidance, such as the need for automatic delivery of NOTAMs from the NDS to at least the facility. It is unclear if or how E-IDS would allocate NOTAMs to individual controllers (e.g., if it would match NOTAMs to controllers based on the affected airport or waypoint), but we suggest that it at least give the option for such an implementation. Similarly, E-IDS promises to provide greater ease of use; we suggest 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 NOTAMs with digital maps so that controllers can, for example, overlay the NOTAM information on an approach plate. We recommend that this feature include options for toggling the information on and off, and adjusting the size and exact location of the NOTAM content (e.g., it could appear over the airport or off to the side with an arrow pointing to the airport). The E-IDS documentation is mute when it comes to options to expand NOTAMs into plain text; we suggest that this at least be an option if not the default.

The value in using Data Comm would depend on how its interface compares to the one already accessible to controllers (e.g. ERIDS) or the future NOTAMs interface in E-IDS. Figure 15 shows a screenshot of the current Data Comm interface, which is notable because 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. Controllers rarely, if ever, create NOTAMs, so they should not need to type the NOTAM. E-IDS could instead provide an option to forward a NOTAM from its interface to an aircraft via Data Comm. For example, an en route controller using the NOTAM interface in ERAM (see Figure 6) 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 NOTAMs and send them simultaneously. Data Comm should provide the same benefits to NOTAMs 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). Specific testing may be needed to determine if there are difficulties on either the controller or the pilot side when multiple NOTAMs need to be communicated; it is possible that some could be missed or not fully understood depending on the interface and the workload of the operators.

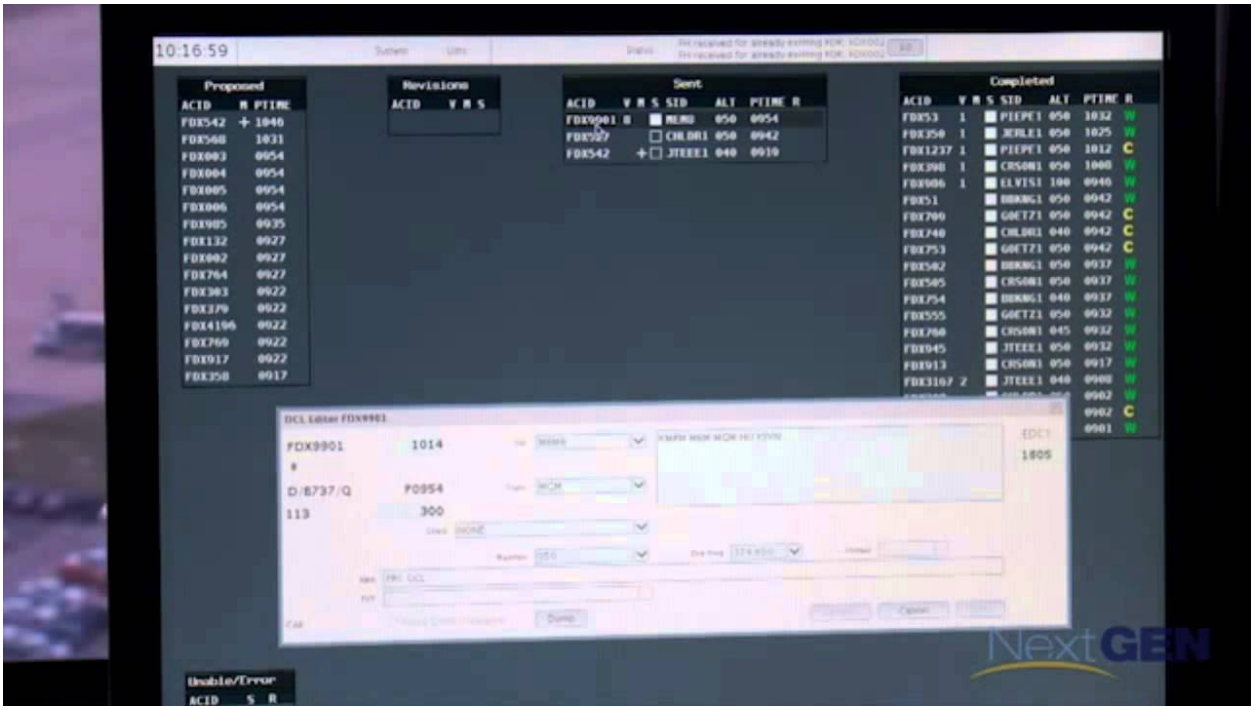


Figure 15. Screenshot of the Data Comm interface (NextGen Data Communications, 2017).

6. CONCLUSIONS

This document has provided a summary of how Notices to Airmen (NOTAMs) are distributed to frontline air traffic controllers and the information display systems that are used to access them. There is a notable disparity in the systems available to terminal and en route controllers, with the terminal systems being both more variable and less automated. In contrast, en route display systems are more uniform and provide better features for controllers from a human factors standpoint.

Beyond this summary, the main goal of the document is to note areas that could be improved in the NOTAMs process from a human factors standpoint. These can be summarized in three broad points:

- The transmission of NOTAMs from the NOTAM Distribution System to the front-line controller should be as automated as possible.
- The display systems should provide flexibility for the controller in regard to information access and display.
- The NOTAM content itself should be simplified to streamline understanding and communication.

Each of these suggestions would involve changes to both the display systems at the controller's position and the infrastructure that supports the NOTAM system. However, the changes should reduce human error in the transmission of NOTAMs from the US NOTAM System to controllers and reduce controller workload.

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Acronyms

ACE – ASOS Controller Equipment
ACE-IDS – ACE Information Display System
AIS – Aeronautical Information Services
AISR – Aeronautical Information System Replacement
ARTCC – Air Route Traffic Control Centers
ASOS – Automated Surface Observing System
ATC – Air Traffic Control
ATCT – Air Traffic Control Tower
ATM – Air Traffic Management
CVFP – Charted Visual Flight Procedure
DP – Departure Procedure
E-IDS – Enterprise Information Display System
ERAM – En Route Automation Modernization
ERIDS – En Route Information Display System
FAA – Federal Aviation Administration
FSS – Flight Services Stations
FLMIC – Front Line Manager In Charge
IAP – Instrument Approach Procedure
ICAO – International Civil Aviation Organization
IDS – Information Display System
IR – Instrument Route
OM – Operations Manager
NAS – National Airspace System
NAVAID – Navigational Aid
NDS – NOTAM Distribution System
NIDS – NAS Information Display System
NOTAM – Notices to Airmen
PIREP – Pilot Report
R - Radar
RA – Radar Associate
RNAV – Area Navigation
SAIDS – Systems Atlanta Information Display System
STAR – Standard Terminal Arrival Routes
SWIM – System Wide Information Management
TFM – Traffic Flow Management
TFR – Temporary Flight Restriction
TRACON – Terminal Radar Approach Control
USNS – United States NOTAM System
VFR – Visual Flight Rules
VOR – VHF Omnidirectional Range

Appendix A: Current IDS Systems

The following is a non-exhaustive list 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

For Front-Line Controllers

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? 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 efficiently and accurately identify any NOTAM (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? 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?

For Managers

NOTAMs

- Who retrieves NOTAMs?
- Where are NOTAMs sent?
- How do you decide to whom NOTAMS should be delivered/how to filter 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? 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?
- Are you able to efficiently and accurately identify any NOTAM (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

- Where are PIREPs sent to?
- 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? 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?
- 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?