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Tower Operations Digital Data System – Concept Refinement and Description of New Features

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Technical Report

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| 16. Abstract Human factors researchers at the Federal Aviation Administration have developed new methods of operation for Air Traffic Control Specialists working in Airport Traffic Control Towers (ATCT). The newly redesigned and enhanced Tower Operations Digital Data System (TODDS) provides a means to assist ATCT controllers with flight data management, communication, and coordination by reducing cognitive and physical taskload. The TODDS prototype designs include separate solutions for ATCTs either with or without surface surveillance capability. This report addresses the results of a recent usability test by providing a description of design changes and new features that compose the TODDS. The author also recommends the use of a touchscreen training protocol. Pending further investigation, the TODDS may help reduce the risk of runway incursions, ease the flow of surface operations, and support the Staffed Virtual Tower concept. | | | | | |
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Executive Summary

As the number of flights and passengers increase and as the technology ages, the Federal Aviation Administration (FAA) must develop new systems to support the National Airspace System (NAS). The Next Generation Air Transportation System (NextGen) Joint Planning and Development Office (2007) outlines the FAA's plan for the future, including a number of new technologies and methods of operation such as System Wide Information Management, Staffed NextGen Tower, digital data communications, and four-dimensional trajectory planning. However, the FAA must conduct a considerable amount of research and development to implement the NextGen concepts. This report discusses ongoing NextGen research and development efforts for Airport Traffic Control Towers (ATCTs).

Currently, air traffic controllers in ATCTs use paper Flight Progress Strips (FPSs) to obtain and record information about each flight under their responsibility. However, the FPSs limit the controllers' ability to share information among themselves and with other facilities, because it is difficult or impossible to enter information recorded on the FPSs into the NAS computers. The FPSs also impose cognitive and physical taskload requirements upon the ATCT controllers.

Engineering Research Psychologists at the FAA have developed a new system for ATCT operations (a) to address the limitations imposed by FPSs and (b) to potentially enable some of the NextGen concepts. Originally called the Electronic Flight Data Interface, the Tower Operations Digital Data System (TODDS) provides a means to assist ATCT controllers with flight data management, communication, coordination, and cognitive and physical taskload. The prototype designs of the TODDS include separate solutions for ATCTs either with or without surface surveillance capability.

This report addresses the results of a recent usability test by providing a description of design changes and new features that compose the TODDS, including integrated weather information, digital communication of taxi-out clearances, taxi-conformance monitoring, an indicator for wake-turbulence separation, and indicators for closed runways and taxiway segments. The author also recommends a touchscreen training protocol for new users of the touchscreen-based TODDS.

1. INTRODUCTION

The Federal Aviation Administration (FAA) is constantly improving the National Airspace System (NAS) to ensure reliability and to enhance capability by utilizing the latest advances in technology. Aging technology and predicted increases in the number of flights and passenger demand necessitate forward thinking and motivate the development of new systems within the NAS. The current FAA plan for the future, the Next Generation Air Transportation System (NextGen) Joint Planning and Development Office (JPDO, 2007), includes several new technologies and methods of operation such as System Wide Information Management (SWIM), Staffed NextGen Towers (SNTs), digital data communications, and four-dimensional (4-D) trajectory planning. The SWIM concept will provide the capability to distribute and share information across the entire NAS. Users and operators within the NAS will be able to subscribe to various sets of information and then have that information provided to them on a real-time basis. The SNT concept reduces the need for physical infrastructure associated with Airport Traffic Control Towers (ATCTs) and will provide a means to control airport traffic from a remote location. The digital data communications concept is already in limited use today for the digital transfer of information between the Airline Operations Centers and pilots and for issuing pre-departure clearances between air traffic service providers and pilots. NextGen proposes to expand the digital communications concept to include information such as digital taxi (D-Taxi) clearances and other non-time-critical air traffic control information. The 4-D trajectory planning concept would take advantage of the digital communications and SWIM concepts to provide real-time information about aircraft movement for trajectory planning and traffic flow management functions. The FAA has described all of these NextGen concepts at a fairly high level on paper, however, it must conduct a considerable amount of research and development to implement the concepts. The current paper discusses ongoing NextGen research and development efforts for ATCTs in particular.

Currently, air traffic controllers in ATCTs, Terminal Radar Approach Controls, and Air Route Traffic Control Centers use paper Flight Progress Strips (FPSs) to obtain and record information about each flight under their responsibility. The FPSs limit the ability to share information between controllers and facilities and make it extremely difficult or impossible to enter recorded information into the NAS computer system. A number of private companies, as well as the FAA, have developed electronic FPS systems for ATCTs to facilitate the sharing, coordination, and recording of pertinent air traffic information. However, all of these electronic FPS systems tend to mimic the paper FPS in both form and function. For example, the typical electronic FPS system replicates the paper FPS information format and places each electronic FPS in a virtual FPS bay. These existing systems capitalize on the controllers' familiarity with the FPS information format and usage and provide the ability to easily transfer and record information. However, they do not address many of the cognitive bottlenecks associated with ATCT operations and flight data management.

1.1 Background

Truitt (2006a, 2006b) examined the ATCT controllers' tasks in an effort to redesign the way controllers manage and interact with flight data. The goal of Truitt's research was to identify cognitive bottlenecks in the ATCT operations and flight data management process and then address these bottlenecks in a way that reduced controllers' mental workload and the probability

of errors that may lead to runway incursions or other more serious errors. Truitt began his research by conducting a literature review (Truitt, 2006b). He then formed a multidisciplinary working group that included ATCT supervisors, software developers, and human factors specialists with advanced degrees in cognitive psychology. The working group used detailed task flows (Alexander et al., 1989; Ammerman, Becker, Jones, Tobey, & Phillips, 1987) to examine the most common ATCT tasks and to identify the information requirements for the ATCT ground and local control positions. The working group also examined the task flows to identify cognitive bottlenecks (tasks that caused ATCT controllers to exert a great deal of cognitive effort) and to identify tasks that could potentially lead to errors or increased risk on the airport surface. We then formed an interface design team, which was a smaller version of the working group and included ATCT controllers, a software developer, and an Engineering Research Psychologist (Truitt, 2006a). The interface design team translated the information generated by the working group into a Graphical User Interface (GUI) form.

The interface design team created two GUIs using a 21.3" VarTech Systems, Inc. touch sensitive display. They also selected the Airport Surface Detection Equipment – Model X (ASDE-X) keyboard and trackball/keypad as additional input devices (see Figure 1). The interface design team created the Integrated Electronic Flight Data Interface (EFDI) to support airports that have surface surveillance capability. They designed the Perceptual-Spatial (P-S) EFDI for airports that do not have surface surveillance capability. For each type of EFDI, the team created separate displays for the ground and local controller positions to accommodate each position's unique information and task requirements (see Figures 2 through 4).



Figure 1. Hardware used to implement the prototype displays including resistive touch display, display mount, keyboard, and trackball/keypad.



Figure 2. The primary elements of the ground controller's Integrated display including the surface situation display, electronic flight data lists, and readout area.



Figure 3. The primary elements of the local controller's Integrated display including the surface situation display, electronic flight data lists, and readout area.



Figure 4. The primary elements of the Perceptual-Spatial display including flight data elements, the readout area, buttons, and system information window.

Truitt (2006a) provides a complete description of the development process, design, and functionality of the initial EFDI prototypes. After completing the initial EFDI designs and creating working prototypes (Truitt, 2006a), we conducted a heuristic evaluation of the EFDIs with the human factors specialists who served on the working group. The results of the heuristic evaluation directed further usability testing involving the ATCT controllers who also served on the working group. During the usability test (Truitt & Muldoon, 2007), the experimenters trained the controller participants to use the Integrated and the P-S EFDIs and then had them work in groups of two (one ground controller and one local controller) to manage flight data while they monitored a recorded airport traffic scenario. The participants had access to simulated surface surveillance information and short-range radar information but did not have an out-the-window view of the airport traffic. Two experimenters observed the participants and collected audio and video data along with GUI interaction data to calculate error rates. The participants also provided subjective feedback to evaluate the usability and effectiveness of the EFDIs and to provide suggestions for additional information requirements and capabilities. The results of the usability test showed that the participants were able to learn how to operate the EFDIs rather quickly. However, they may not have had enough time to learn how to use the touch sensitive displays reliably. For the Integrated EFDI, the participants had an error rate of 16% during the practice and 12% during the test. For the P-S EFDI, the participants had an error rate of 7% during the practice and 8% during the test. The relatively high error rates resulted from a few EFDI actions that the participants had difficulty performing. Overall, the participants' responses to the EFDIs were favorable. The participants thought the EFDIs were well organized and easy to use. They thought that the EFDIs required little effort, provided all of the necessary flight data, and supported their awareness of the airport traffic situation. However, there were several functions that were difficult to use, which may have contributed to the participants'

concerns that the EFDIs may cause too much *head down* time and may be labor intensive in some situations. The results of the usability test generated recommendations to improve the usability of the EFDIs and provided suggestions for new features.

Due to the expanding scope of the EFDIs' capabilities, we changed the name to the Tower Operations Digital Data System (TODDS) to better describe the concept's breadth and to distinguish it from existing Electronic Flight Data systems. This report describes changes made to the initial design concepts by referring to the EFDIs and describes new features by referring to the TODDS. The overall redesigned concepts are also called TODDS.

1.2 Purpose

The current report describes how we addressed the results of the usability test (Truitt & Muldoon, 2007) and presents new features that expand the EFDI capability into the TODDS. In particular, (a) we discuss the need for improved training procedures for using the touch sensitive display, (b) we discuss how we improved the usability of the most difficult-to-use elements, and (c) we discuss new features that we implemented based on the participants' suggestions and as a need to expand the scope of the EFDI capabilities.

2. ADDRESSING THE RESULTS OF THE USABILITY TEST

2.1 Common Issues

This report presents our response to the results of the usability test. In particular, we discuss touchscreen training, as well as present solutions for the identified usability issues for the Automated Terminal Information Service (ATIS) Update indicator, acknowledging expired aircraft specific and generic timers, the Flight Data Amendment indicator, acknowledging flashing Expected Departure Clearance Times (EDCTs), Hold Short indicator, timer interface placement, and we present new features for ownership highlighting, and history and recall of Flight Data Elements (FDEs). These usability issues and new features apply to both the Integrated and P-S EFDI prototypes.

2.1.1 Touchscreen Training

One of the primary findings of the usability test was that controllers need to learn how to operate the interface, but they also need considerable training in using the touch sensitive display itself. Most people have some experience with computers and GUIs and are typically adept at using a keyboard, mouse, and maybe even a trackball or joystick. However, interacting with a touch sensitive display is much less common in everyday applications. The VarTech Systems, Inc. touch sensitive display is a resistive display that responds to pressure on its screen. Therefore, learning how to apply the right amount of pressure and maintaining that pressure while performing actions, such as dragging an element across the screen, is something that takes more training than we provided in the usability study. The VarTech Systems, Inc. display, like the common Cathode Ray Tube displays, can also present some degree of visual parallax, depending on the user's viewing angle. We did not provide adequate training for the controller participants in the usability study to be able to compensate for visual parallax and the requirements of the resistive touch sensitive technology. The relatively high error rates in the usability study were likely due to a combination of the participants' lack of familiarity with the touch sensitive display and the design of the elements presented on the display.

To address the users' lack of familiarity with the touch sensitive display, we designed a touchscreen training protocol to give users experience with basic touchscreen operation. The training protocol requires users to repetitively perform three separate tasks with 10 different button sizes. The users start with the largest button size and perform a number of trials for each of three tasks using the same button size. The first task is to select a single button. The second task is to select two buttons in succession. The third task is to drag a button to a target area. For each trial, the buttons and target area in the dragging task appear at a random location on the screen. If more than one button is present at a time, the buttons never overlap and the button in the dragging task never overlaps the target zone. The software provides immediate visual feedback to the user to let them know whether they succeeded or failed a trial. After completing trials for all three tasks on the largest button size, the users repeat each of the three tasks using a smaller button size until they have completed all tasks for all button sizes. The touchscreen training protocol requires that the users complete a minimum number of trials, and they must successfully perform a number of trials in succession before moving on to the next task. The training protocol also establishes a maximum number of trials for each task. If a user reaches the maximum number of trials, the task ends and the software continues by presenting the next task. The software provides feedback to the users during each task to let them know how they are progressing.

We are currently conducting pilot studies to determine the parameters for the minimum and maximum number of trials. We expect that the training protocol will provide users with about 2.5 to 3 hours of training with the touch sensitive display. After completing the training protocol, we expect that users will be much better prepared to use the touch sensitive display and any usability problems that we detect subsequently will be due primarily to the interface design and not due to the user's experience with touch sensitive displays. Therefore, the touchscreen training protocol should allow us to obtain more reliable and valid estimates of errors rates associated with our prototype interface designs.

2.1.2 ATIS Update Indicator

One design element of the EFDIs that was particularly troublesome for the participants, due to its small size, was the ATIS Update indicator. The ATIS Update indicator appears as a box on the right side of an FDE (see Figure 5).



Figure 5. The ATIS Update indicator and ATIS code (shown in yellow) as displayed in the Integrated (top) and P-S (bottom) EFDIs.

Controllers select the ATIS Update indicator once they have verified that the pilot has the current ATIS information, which removes it from the FDE. The ATIS update indicator automatically returns to the FDE if there is an update to the ATIS information.

The participants made an error in selecting the ATIS Update indicator 33% of the time in the Integrated EFDI and 26% of the time in the P-S EFDI (Truitt & Muldoon, 2007). We increased the size of the selectable area around the ATIS Update indicator to improve the user's ability to select this element. We also implemented a means to undo an ATIS update acknowledgment. In the initial EFDI design, there was no way for the user to recover from inadvertently acknowledging an ATIS Update indicator. The user can now undo an inadvertent acknowledgment of an update indicator by selecting the FDE or data block of the aircraft and then selecting the current ATIS code that appears on the situation display. We also moved the location of the current ATIS code from the system area (as shown in Figure 5) and integrated it with the weather information panel (as described in section 3.1).

2.1.3 Aircraft Specific and Generic Timers

Controllers can use the EFDI to set a generic timer or set a timer and associate it with a particular aircraft. Associating a timer with an aircraft places a timer icon on the right side of the FDE. When the timer expires, the timer icon flashes briefly and then remains highlighted in yellow (see Figure 6). The controller can acknowledge an expired timer by selecting the timer icon. Although the participants rarely used the aircraft specific timer during the usability test, they had difficulty selecting the expired aircraft specific timer with error rates of 50% and 38% in the Integrated and P-S EFDIs, respectively. Therefore, we increased the size of the selectable area around the expired aircraft specific timer to make this element easier to select.



Figure 6. The expired aircraft specific timer icon on an FDE in the Integrated (top) and P-S (bottom) EFDIs.

In the initial design, the aircraft specific timer was not transferred when the controller passed an FDE to another controller position. The usability test participants requested that an aircraft timer remain associated with an aircraft's flight data regardless of controller position. Therefore, we changed the design of the aircraft specific timer; when a controller assigns an aircraft specific timer, that timer remains with the aircraft's FDE even after the controller transfers the FDE to another controller position. For example, the ground controller may set an aircraft specific timer and then pass to the FDE to the local controller. If the timer has not expired, the local controller will receive an FDE with an associated aircraft specific timer that is running and will expire while at the local controller's position if the local controller does not cancel the timer or transfer the FDE before the timer expires.

The usability test participants also told us that both the expired generic timer and the expired aircraft specific timer lacked salience. Whenever one of these timers expires, we now flash the timer text or timer indicator itself, but we also flash the timer's background to increase the salience. Figure 7 shows the initial expired generic timer design and the new expired generic timer design. Figure 8 shows the new expired aircraft specific timer design.

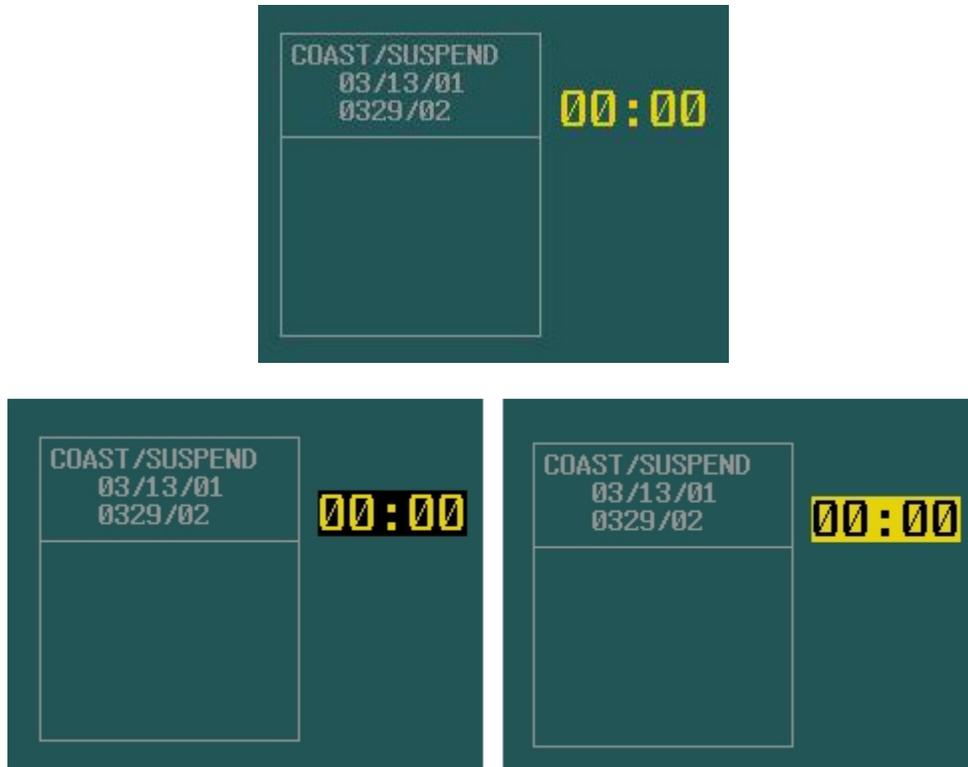


Figure 7. Initial generic expired timer design (top) and new generic expired timer design (bottom left and right).



Figure 8. New Integrated (top) and P-S EFDI (bottom) aircraft specific expired timer design.

2.1.4 Flight Data Amendment Indicator

When a controller enters a flight data amendment for an aircraft such as a change to the assigned heading or altitude, an indicator (an asterisk) appears on the right side of the aircraft's FDE (see Figure 9).



Figure 9. The Flight Data Amendment indicator on an FDE in the Integrated (top) and P-S (bottom) EFDIs.

In the initial design of the EFDI, the Flight Data Amendment indicator appeared only at the controller position where the controller entered the amendment. Once the controller acknowledged the amendment by touching the highlighted flight data in the readout area, the Flight Data Amendment indicator disappeared and the next controller who received the flight data was unaware that the previous controller had performed an amendment. The usability test participants suggested that although the Flight Data Amendment indicator can and should be acknowledged at the originating controller's position, other controllers who subsequently receive the flight data should also be notified of the amendment. Therefore, we adapted the Flight Data Amendment indicator to persist at the next controller position even though the previous controller had acknowledged it.

2.1.5 Acknowledge Flashing EDCT

If an aircraft has an EDCT, it occupies the time field of the FDE and appears highlighted. As the EDCT approaches, the highlighting changes colors and flashes for a period of 15 s (see Figure 10). The EDCT flashes yellow 10.5 min prior to the EDCT and flashes orange 30 s before the EDCT. The usability test participants thought that the flashing EDCT could be distracting and recommended that controllers have the option to stop the flashing before the 15 s period expired. Therefore, we redesigned the EDCT to provide controllers the option to select an EDCT time field to stop the flashing.



Figure 10. The EDCT highlighting on an FDE in the Integrated (top) and P-S (bottom) EFDIs.

2.1.6 Hold Short Indicator

The usability test participants also wanted the ability to indicate which aircraft they had given a hold short clearance. Therefore, we added a hold short button to both the Integrated and P-S EFDIs. To add the Hold Short indicator to an aircraft, the controller selects an aircraft FDE or data block and then selects the hold short button. This sequence of actions adds the Hold Short indicator (a dashed vertical line) to the left side of the FDE or data block, as appropriate, and automatically deselects the data block and/or FDE (see Figure 11). Once in place for an aircraft, the Hold Short indicator appears on both the ground and local controller positions. A controller can remove a Hold Short indicator by selecting an aircraft's FDE or data block that contains a Hold Short indicator and then selecting the hold short button. This action removes the Hold Short indicator and automatically deselects the respective data block and/or FDE.



Figure 11. The hold short button and indicator on a data block in the Integrated EFDI (top) and on an FDE in the P-S EFDI (bottom).

2.1.7 Timer Interface Placement

Another issue that we identified in the usability test was that the controller could place the timer interface in the same location as the readout area (upper corner of the interface), thereby rendering the aircraft specific timer useless. To set an aircraft specific timer, the controller must select an aircraft data block or FDE and then open the timer interface by selecting the system area. However, selecting an aircraft data block or FDE also activates the readout area. Therefore, selecting an aircraft to set the aircraft specific timer may lead to the timer interface becoming obscured partially or entirely by the readout area. We redesigned the prototypes to prevent the controller from placing the timer interface in the area occupied by the readout area. The readout area now occupies a protected zone on the interface, and the controller cannot place any other interface elements (e.g., buttons, timer interface) within it. Figure 12 shows the readout window and the movable timer interface located in the upper corner of the display.

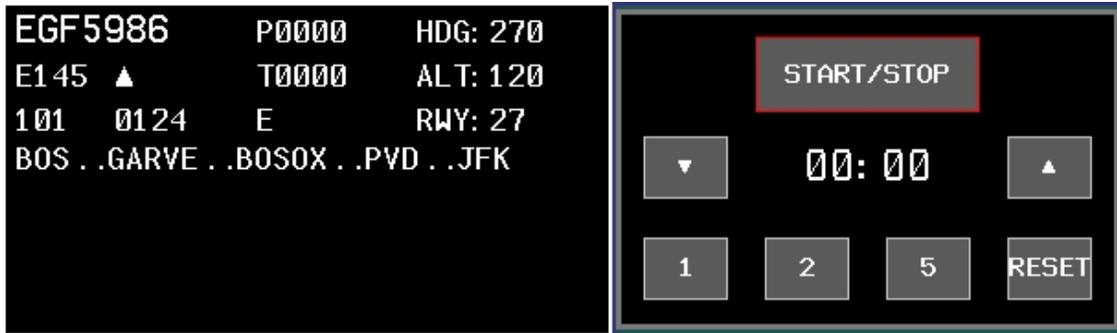


Figure 12. The readout area (left) is a protected area that other elements cannot occupy, including the timer interface (right).

2.1.8 Ownership Highlighting

The EFDIs use color to indicate ownership. Aircraft that are the responsibility of a particular controller position appear with white text in the FDE and data block, leader line, and position symbol in the Integrated EFDI. Aircraft that are not under a particular position's responsibility appear with gray text and symbology. In the initial design, highlighting flight data caused the associated select outline, and in the Integrated design, the leader line and aircraft position symbol, to also change color. Thus, generic highlighting or highlighting as a result of Taxi-into-Position-and-Hold (TIPH) status removed the color coding associated with ownership (see Figure 13). We modified the design so that highlighted flight data affects only the text, thus preserving the ownership information (see Figure 14).



Figure 13. A highlighted aircraft in the Integrated (top) and P-S EFDI (bottom) loses ownership information.



Figure 14. A highlighted aircraft in the Integrated EFDI (top) and a selected and highlighted FDE in the P-S EFDI (bottom) retains ownership information.

2.1.9 FDE History and Recall

The initial EFDI design included the ability to transfer an FDE to another controller position or facility and to retrieve an FDE after it had been passed. However, the design of the FDE recall feature was not complete at the time of the usability test, and we did not train the participants on how to use this feature. The usability test participants stated that they wanted such a feature and, in fact, discovered the partially implemented FDE recall feature on their own. We completed the design of the FDE recall in the current version of the prototypes.

Controllers can pass flight data from one controller position to another by selecting an aircraft data block or FDE and then selecting the appropriate button to transfer the flight data. To recall the flight data, the controller can select the button of the position or facility that currently has the data to see a recent history of the FDEs passed to that controller or facility (see Figure 15). The controller then selects the FDE they wish to recall and selects the appropriate transfer button to return the FDE to the associated list. Because the list history contains only the most recent FDEs that the controller passed to a particular position or facility, a controller cannot retrieve older FDEs without consent and action on behalf of the controller who currently possesses the FDE.

| LOCAL HISTORY | | | | |
|---------------|---------|------|----------|------|
| Δ | AAL833 | B738 | GARVE 27 | 0000 |
| Δ | EGF5986 | E145 | GARVE 27 | 0000 |
| Δ | USA447 | A333 | GARVE 27 | 0000 |

| LOCAL HISTORY | | |
|---------------|-------|------|
| COA254 | GARVE | 0002 |
| B735 | 27 | |
| AAL833 | GARVE | 0001 |
| B738 | 27 | |
| AAL874 | MALDY | 0001 |
| B763 | 33L | |

Figure 15. The FDE history list for the Integrated (top) and P-S (bottom) EFDIs.

2.2 Interface-Specific Issues

All of the previously discussed changes apply to both the Integrated and the P-S EFDIs. However, because these separate designs contain some unique features based on their respective capabilities, we discovered some usability problems that are unique to one design or the other. For the P-S EFDI design, we increased the size of at the top of the FDE zones, added animation to FDE movement in the zones, and provided a way to undo an errant TIPH indicator. For the Integrated EFDI design, we changed the organization scheme of the departure list and added an indicator to show when an aircraft is moving on a runway surface.

2.2.1 P-S EFDI – FDE Zone Behavior

In the initial P-S EFDI design concept (Truitt, 2006b), we created FDE zones to help the controller organize and manage the FDEs. There are three primary zones for departure FDEs, as Figure 16 shows. The zones work by linking together FDEs that are inside a zone. If the controller places an FDE in a zone that does not contain any FDEs, the FDE will occupy an anchor position at the top of the zone. When the controller places another FDE in a zone, it links to the FDE occupying the anchor position to form a chain (see Figure 17). Moving an FDE out of a zone causes the other FDEs in the zone to move together and make room for more FDEs. The FDE zone also allows controllers to resequence FDEs in the zone. Moving an FDE to a new position in the zone causes it to rejoin the chain in its new position.

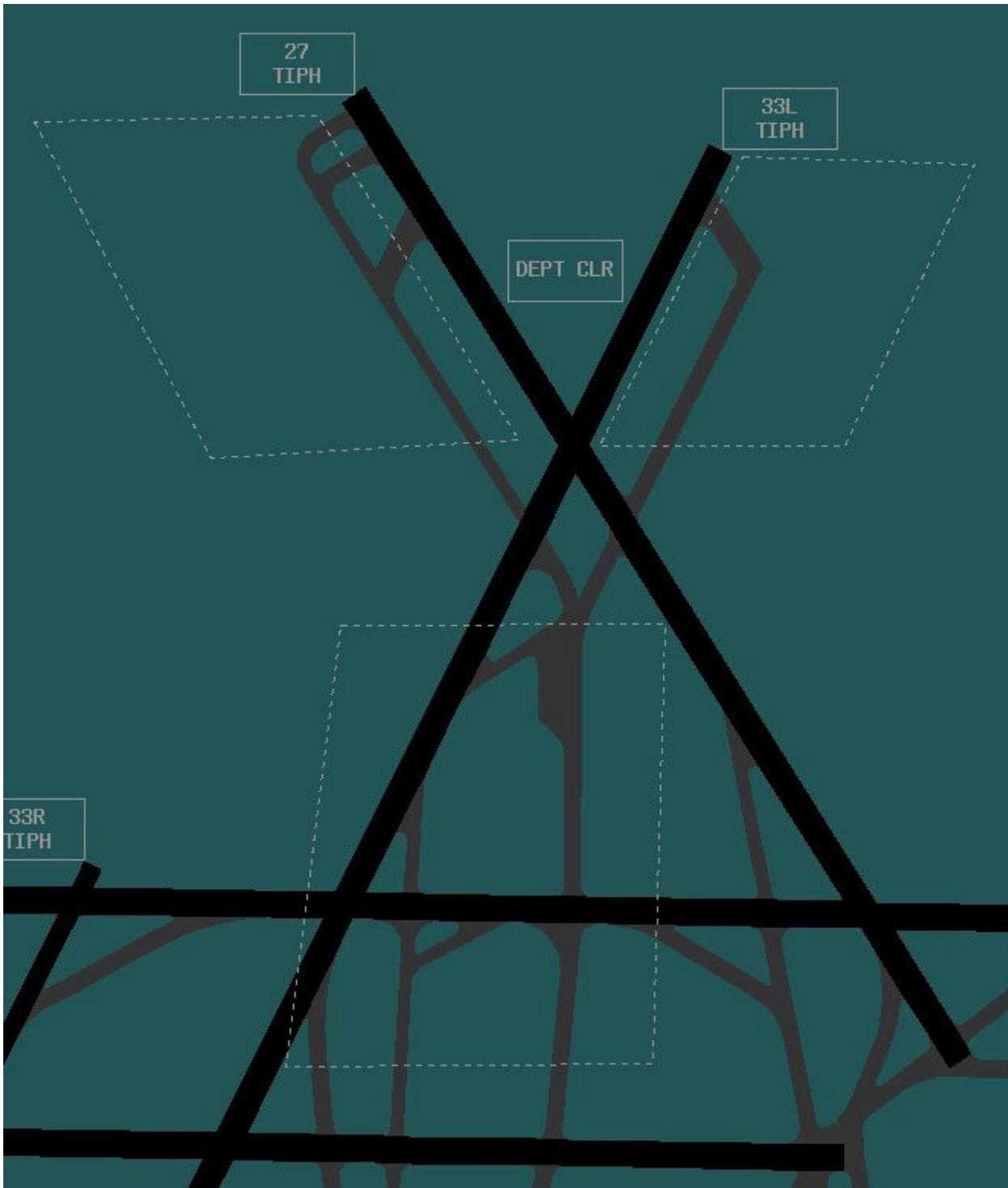


Figure 16. FDE zones used to organize and manage departure FDEs. The lines defining the FDE zones are not visible to the controller.

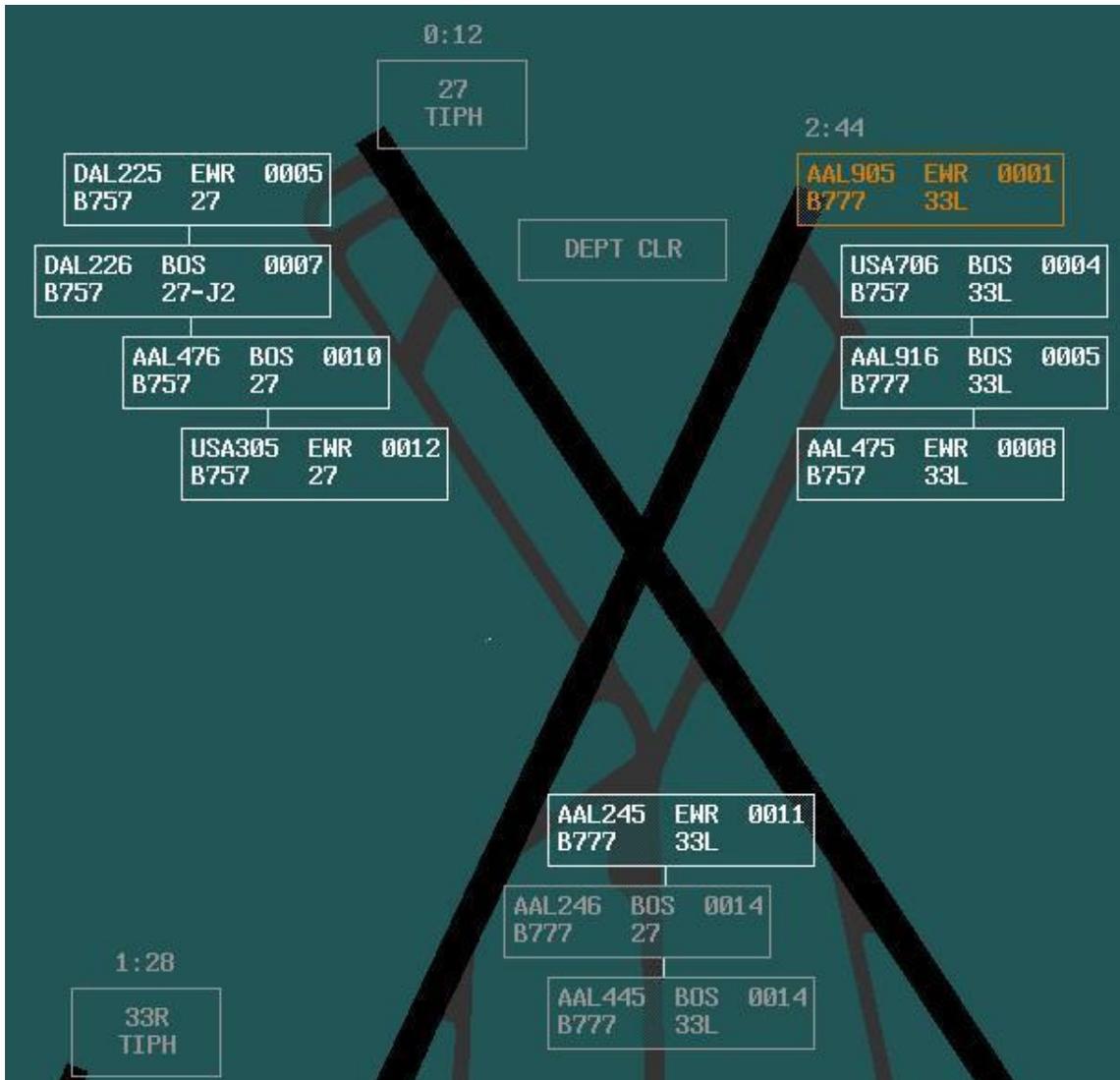


Figure 17. FDEs linked inside the FDE zones.

One problem we identified during the usability test occurred when controllers tried to resequence an FDE to the top of a chain. The participants had difficulty moving an FDE to the topmost anchor position in a zone because there was very little space between the top of the FDE in the anchor position and the top of the zone. Thus, resequencing an FDE to the top of a zone required a very precise drag and drop movement. We addressed this problem by increasing the size of the space between the FDE in the anchor position and the top of the zone.

Furthermore, when controllers did manage to resequence FDEs within a zone, the P-S EFDI did not provide good feedback to the controllers about what action had taken place. Resequencing an FDE simply rearranged the FDEs very quickly with very little visual feedback that an action had taken place. To correct this problem, we added animation to the FDE zones so that when the controller places an FDE in a new position within a zone, the controller can see the FDEs move into their new positions.

2.2.2 P-S EFDI – TIPH Undo

The usability test participants commented that there were times when they wanted to undo an action but were unable to do so. During the usability test, we observed that controllers could place the wrong FDE into TIPH status. To place an aircraft FDE in TIPH status, the controller selects an FDE and then selects the TIPH button for the appropriate runway. The FDE then occupies a position at the end of the appropriate runway and the FDE text appears highlighted in orange (as shown in Figures 13 and 17). Once an FDE enters TIPH status, the controller could not reverse the action. Therefore, we augmented the TIPH clearance to allow controllers to drag an FDE out of the TIPH location and place it back on the surface map or back into an FDE zone. When the controller drags an FDE out of TIPH status, the FDE text reverts to the previous color (white on the local controller’s display, gray on the ground controller’s display, or cyan) if it was highlighted prior to achieving TIPH status.

2.2.3 Integrated EFDI – Organization and Separation of the Departure List

The original Integrated EFDI design organized the departure aircraft list on the local controller’s display based on the overall departure sequence from the airport. As Figure 18 shows, the FDEs for aircraft departing from different runways are interspersed. However, the usability test participants commented that they would rather have the departure aircraft list organized based on the sequence for each runway. Therefore, as Figure 19 shows, we modified the operation of the departure list so that a subtle, yet noticeable divider separates FDEs for aircraft that are departing from different runways. The divider creates the equivalent of a separate bay within the departure list. Departure FDEs transferred from the ground controller to the local controller appear at the top of the appropriate bay within the local controller’s departure list. If the controller resequences the FDEs, causing the FDEs for aircraft departing from different runways to become interspersed within the list, multiple separator lines are automatically generated to create additional subsets of bays (see Figure 20).

| DEPARTURE | | | | | |
|-----------|------|-----|-----|-------|--------------------------|
| AAL916 | B777 | BOS | 04L | 0006 | <input type="checkbox"/> |
| USA706 | B757 | BOS | 09 | 0004 | |
| AAL906 | B777 | BOS | 04L | 0003 | |
| AAL915 | B777 | BOS | 04L | 0002 | |
| USA705 | B757 | EWR | 04L | 0001 | |
| AAL905 | B777 | EWR | 04L | 01:27 | |
| | | | | | |

Figure 18. The original design for the departure aircraft list on the local controller’s position.

| DEPARTURE | | | | |
|-----------|---------|------|-----------|------|
| ▲ | SWA408 | B738 | MALDY 33L | 0004 |
| ▲ | DAL247 | B752 | MALDY 33L | 0003 |
| ▲ | AAL874 | B763 | MALDY 33L | 0002 |
| ▲ | EGF5986 | E145 | GARVE 27 | 0005 |
| ▲ | COA254 | B735 | GARVE 27 | 0003 |
| ▲ | AAL833 | B738 | GARVE 27 | 0002 |
| | | | | |

Figure 19. The revised design for the departure aircraft list on the local controller's position.

| DEPARTURE | | | | |
|-----------|---------|------|-----------|------|
| ▲ | SWA408 | B738 | MALDY 33L | 0004 |
| ▲ | DAL247 | B752 | MALDY 33L | 0003 |
| ▲ | EGF5986 | E145 | GARVE 27 | 0005 |
| ▲ | COA254 | B735 | GARVE 27 | 0003 |
| ▲ | AAL833 | B738 | GARVE 27 | 0002 |
| ▲ | AAL874 | B763 | MALDY 33L | 0002 |
| | | | | |

Figure 20. The departure aircraft list automatically creates separators for interspersed FDEs.

2.2.4 Integrated EFDI – Indicator for Aircraft Moving on a Runway Surface

In the original Integrated EFDI design, there was no visual highlighting of aircraft that were moving on a runway surface. Because aircraft moving on a runway surface can pose a potentially hazardous situation, the usability test participants recommended highlighting aircraft that are moving on or across a runway surface. We modified the Integrated design so that an aircraft moving on a runway surface during takeoff, landing, or taxi operations causes the associated data block and FDE to highlight with yellow text (see Figure 21). The color of the leader line and position symbol preserves ownership information. The yellow highlighting reverts to its appropriate ownership or highlighted color after leaving the runway surface.

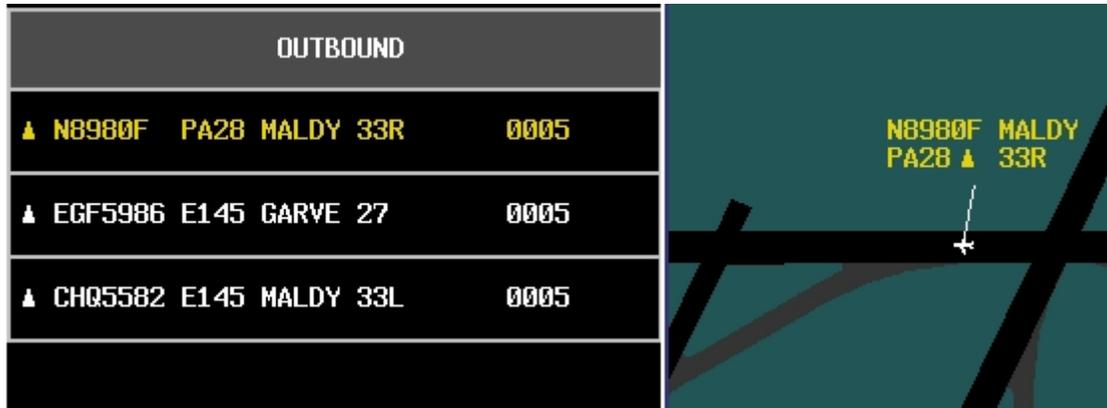


Figure 21. Aircraft moving on or across a runway surface causes the data block and FDE text to appear highlighted in yellow.

3. NEW FEATURES – THE TOWER OPERATIONS DIGITAL DATA SYSTEM

The original EFDI prototypes were limited in scope in that they addressed only the most common tasks performed by the ground and local controller positions. After the initial evaluations of the EFDIs, we expanded the scope of capabilities to include other controller tasks and to integrate other important information sources. We also wanted to address future concepts as proposed by the NextGen plan (JPDO, 2007). Therefore, we integrated basic weather information, an indicator for wake turbulence separation and indicators for closed runway and taxiway segments, D-Taxi out clearance, and taxi conformance monitoring for aircraft that received a D-Taxi clearance. These new features, combined with the existing (Truitt, 2006b) and enhanced EFDI prototype designs presented in this report, compose the TODDS. We worked with Subject Matter Experts (SMEs) to design these new features, but SMEs other than those on the interface design team have not evaluated them. An informal heuristic evaluation by human factors specialists indicated that the new features are promising, but further evaluations of their design and usability are necessary.

3.1 Weather Information

The ATCT controllers today acquire real time weather information from sensors located on or near the airport surface. This weather information is available in the ATCT via a direct readout dial mounted in the ATCT console, a wind shear detection system, an Automated Weather

Observation System display, or the computerized Information Display System display. One way the TODDS prototypes reduce cognitive and physical taskload is by integrating information into a single display. Integrating information that is normally dispersed throughout the ATCT cab reduces the controllers need to shift their visual attention and provides information in a readily accessible format. Therefore, we decided to integrate the most-often-used weather information into the TODDS prototypes.

We determined the weather information requirements for ATCT controllers by using the same task flow analysis procedure employed in the original design process for the EFDIs (Truitt, 2006b). Instead of reconvening the entire working group, we established the necessary information requirements by using the members of the multidisciplinary interface design team consisting of ATCT SMEs, a human factors specialist, and a computer software engineer. By examining the controller tasks, we determined that the most important weather information needs included the wind speed, wind direction, gust speed, altimeter reading, and runway visual range (RVR) for the active runways at touchdown, midpoint, and rollout. Although pilots can get weather information by listening to the recorded ATIS information, the ATIS does not present information in real time and can be outdated by as much as 1 hour. The ATCT controllers at the ground and local control positions communicate real-time information to pilots to inform them of the most current weather conditions at the airport.

To integrate the weather information into the TODDS prototype designs, we created a small, movable box that contained all of the important elements (see Figure 22). The first line of the weather information box displays the current ATIS code, wind direction, wind speed, gust speed, and altimeter reading. A single letter ranging from A through Z indicates the current ATIS code.



Figure 22. The weather information box.

The wind direction, wind speed, and gust speed appear as a combined information element containing six digits and one character. The first three digits indicate the wind direction, which ranges from 010 to 360 and changes in increments of 10. The next two digits indicate the wind speed in knots, which ranges from 00 to 99 and changes by increments of one. The letter G and

two digits that indicate the wind gust follow the wind direction. The wind gust is represented by two digits ranging from 01 to 99 and changes by increments of one. The wind gust information appears only if a wind gust is present. The current altimeter reading also appears on the first line of the weather information box, separated from the wind information, and includes four digits. We decided to present the weather information in this format because it coincides with how controllers actually use the information and communicate it to pilots. For example, the controller may give the current weather information to a pilot as, “Winds, two three zero at eleven, gusting to fifteen; altimeter, two niner niner five.” Subsequent lines of the weather information box display the RVR information. Each line indicates an active runway and its associated RVR at the touchdown (T), midpoint (M), and rollout (R) in hundreds of feet. If an RVR reading is greater than 6,000 feet, a plus sign will accompany the reading (e.g., T60+). Improper runway lighting conditions at night can produce erroneous RVR readings. Therefore, if the RVR system detects an improper runway light setting, the weather information box displays the message, LIGHTS. The weather information box includes a handle on the top that controllers can use to drag the box to a different location on the TODDS. When a controller touches the handle of the weather box, the handle highlights to provide visual feedback.

3.2 Wake Turbulence Indicator

ATCT controllers currently must consider wake turbulence when instructing aircraft to land and depart according to FAA Order 7110.65S, section 9, 3-9-6 and 3-9-7 (FAA, 2008). The FAA is working on new wake turbulence detection systems that take into account wind speed and wind direction to determine situations where the effect of wake turbulence is mitigated. The Wake Turbulence Detection system has the potential to tell controllers when wake turbulence is or is not a factor and allows them to space aircraft closer together during *arrival to* and *departure from* the airport. Such a system could improve airport capacity without impacting safety. However, a Wake Turbulence Detection system would also place yet another display in the ATCT, to which controllers must attend, requiring additional shifts of visual attention and increased cognitive and physical taskload. Therefore, we decided to integrate a Wake Turbulence indicator into the TODDS prototypes.

The Wake Turbulence indicator appears as a set of chevrons at the departure end of a runway, as Figure 23 shows. The controller must use standard separation for wake turbulence when the Wake Turbulence indicator appears on the runway. When the Wake Turbulence indicator is *not* present, the controller can suspend the standard rules governing wake turbulence separation. This design concept demonstrates how new systems can be integrated into the TODDS design to prevent controllers from engaging in unnecessary shifts of visual attention.

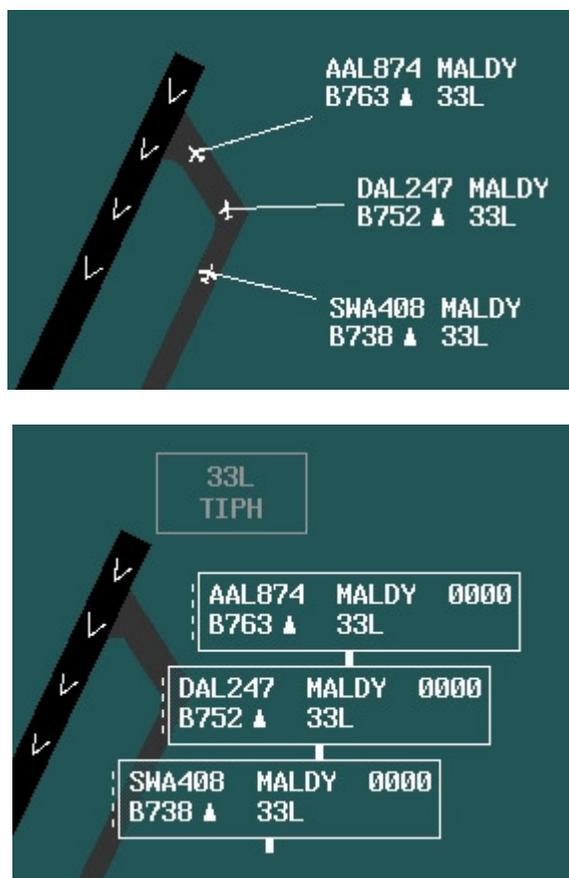


Figure 23. The wake turbulence indicator in the Integrated (top) and P-S (bottom) TODDS.

3.3 Closed Runway and Taxiway Segment Indicator

Occasionally, all or a portion of a runway or taxiway is closed. Airport authorities may close a portion of the airport surface for a variety of reasons, including lighting maintenance, surface maintenance, or the presence of a foreign object. The ATCT controllers typically receive an FPS to notify them of the closure, but they do not have other types of reminders. If a controller forgets that a portion of the airport surface is closed, a dangerous situation could occur such as a runway incursion or collision. A controller's failure to inform a flightcrew about a closed taxiway contributed to the following incident, as documented by the National Transportation Safety Board (NTSB).

NTSB Identification: MIA96LA107
 Accident occurred Wednesday, March 27, 1996 in Memphis, TN
 Aircraft: Boeing 727-225, registration: N468FE

A [Notice to Airmen] NOTAM had been issued by the airport authority for closure of the portion of Taxiway A, between the entrance to the Northwest Airlink hangar and Taxiway B. Although the NOTAM had been sent to the FAA Tower and Federal Express, the flightcrew was not provided this NOTAM by Federal Express, and the closed taxiway was not blocked off. The flightcrew received ATIS information 'Alpha' about 120 miles from Memphis,

but the controller, who had recorded the ATIS, did not include the NOTAM information. About 20 minutes before the flight landed, the ATIS was changed to information 'Bravo,' which included the NOTAM information. The flightcrew did not get information 'Bravo,' and the approach controller did not ensure that the flightcrew had the most current information. After landing, the flight was cleared to taxi and hold short of runway 27. The ground controller did not inform the flightcrew that taxiway 'A' was closed. The flight proceeded along the closed portion of taxiway 'A,' and as the flightcrew was maneuvering around construction equipment, the right wing of the aircraft struck the construction equipment.

The National Transportation Safety Board determines the probable cause(s) of this accident as follows: failure of the flightcrew to maintain clearance from construction equipment while taxiing after landing. Factors relating to the accident were: failure of operator personnel to supply the flightcrew with current NOTAM information, failure of ATC personnel to include NOTAM information on ATIS information 'Alpha,' failure of tower personnel to ensure that the flightcrew had the most current ATIS information, failure of the ground controller to control the movement of the aircraft to prevent it from entering the closed taxiway, and failure of the airport authority to block the closed taxiway (NTSB, 1997).

We decided to add an indicator to both the Integrated and P-S TODDS to remind ATCT controllers of areas of the airport that are closed to aircraft operations. The controller at either the ground or local control position can activate the Closed Runway and Taxiway Segment indicator. The controller activates the indicator by selecting the button to close either a runway or taxiway surface (see Figure 24).



Figure 24. The closed runway and taxiway indicator edit buttons.

Selecting the Edit Runway button removes the aircraft tracks and data blocks in the Integrated TODDS, removes the FDEs in the P-S TODDS, and highlights the runway segments with a white outline. The airport map appears divided into three sections, and a new set of buttons appears (see Figure 25). The controller can select one of the buttons to close an entire runway.



Figure 25. The closed runway edit screen including airport sectors and buttons in the Integrated TODDS.

To close a segment of a runway, the controller selects the section of the airport that contains the runway segment. The view will zoom in to the selected section to increase the view size for that section and, hence, increase the size of the segments contained in that section. We implemented this zoom function to make it easier to select the segments, because some of the segments are too small for a touchscreen application. The controller then touches the segment to close, and the segment appears highlighted with a subtle, yet distinct, reddish-brown color (see Figure 26). Selecting a highlighted segment removes the highlighting.



Figure 26. Highlighted runway segments in the zoomed editing view.

Once the controller has selected the runway or runway segments to indicate as *closed*, he or she selects the Edit Runway button again to return to the normal view. The closed runway segments then appear highlighted on both the ground and local controller positions (see Figure 27).



Figure 27. The closed runway and runway segment indicators on the Integrated TODDS.

A controller can indicate a closed taxiway segment the same way as for a runway segment. The controller selects the Edit Taxiway button, which removes the aircraft tracks, and a sectioned map of the airport surface that highlights each of the taxiway segments with a white outline (see Figure 28) replaces the data blocks on the Integrated TODDS and the FDEs on the P-S TODDS.



Figure 28. Highlighted taxiway segments in the editing view on the Integrated TODDS.

The controller then selects the section of the airport containing the taxiway segments to indicate as closed, and the view zooms in to that section of the airport surface map. The controller then selects the appropriate taxiway segments to activate (or deactivate) the highlighting (see Figure 29). The controller selects the Edit Taxiway button again to return to the normal view where the highlighted segments appear on both the ground and local controller positions (see Figure 30).



Figure 29. Selected closed taxiway segment indicators in the zoomed editing view of the Integrated TODDS.



Figure 30. The closed taxiway segment indicators on the Integrated TODDS.

We chose to use color highlighting rather than graphics (e.g., X's or hash marks) to indicate a closed runway or taxiway segment because graphics would not always display properly for smaller segments and surfaces displayed in certain orientations. We decided to remove the FDEs, aircraft tracks, and data blocks during the runway/taxiway segment-editing task because we do not expect controllers to use this function very often and the entire function takes only a few seconds to complete. Because the TODDS prototypes link the ground and local controller positions to one another, any change to a runway or taxiway indicator on one controller's display is reflected on the other controller's display. The linked displays allow controllers to communicate and remember information about closed runways and taxiways without direct verbal communication or increased memory load, thereby reducing the possibility of miscommunication or memory lapse.

3.4 Digital Taxi Out Clearance

The JPDO NextGen plan calls for an increase in the use of digital communications (JPDO, 2007). One way the JPDO plans to use digital communications in ATCT operations is for D-Taxi out clearances. Therefore, we decided to implement D-Taxi out clearances into the TODDS prototypes. The D-Taxi out clearance works the same way in both the Integrated and P-S TODDS, except that the P-S TODDS contains only FDEs, whereas the Integrated TODDS contains both FDEs and data blocks. The Integrated TODDS can also use the D-Taxi out clearance to perform taxi conformance monitoring (as described in section 3.5).

If a departure aircraft has the ability to conduct digital data communications, a triangle-shaped Digital Data Communications Indicator (DCI) appears in the aircraft's associated FDE and data block. In the Integrated TODDS, the DCI appears to the left of an aircraft's call sign in the FDE and in the middle of the second line in a data block. In the P-S TODDS, the DCI appears in the middle of the second line of an FDE. An open triangle indicates that the associated aircraft's flight data are owned by another controller position. A closed triangle indicates that the flight data are owned by the current controller position (see Figure 31). A controller can send a D-Taxi clearance to owned aircraft only. The ownership color-coding convention applies to the DCI in a manner that is consistent with other color-coding conventions in the TODDS prototypes. The DCI appears gray for an aircraft whose flight data are in a pending state or owned by another controller position, or it appears white if the data are in an active state and belongs to the current controller position.

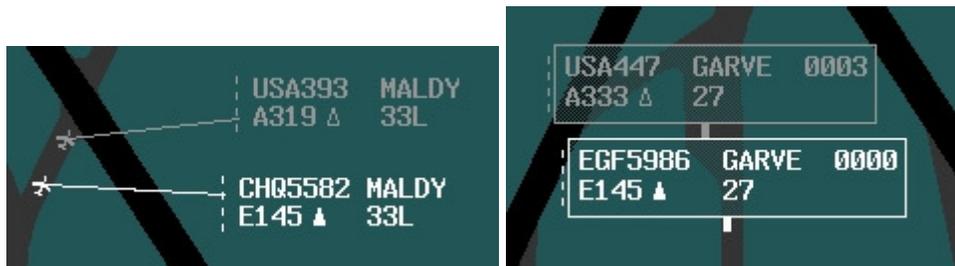


Figure 31. The DCI in the Integrated (left) data block and P-S (right) TODDS prototype FDE.

Once a departing aircraft appears in a pending state on a predetermined ramp spot, the flight data, including the DCI, appears in gray on both the ground and local controller positions. After reaching the ramp spot, the aircraft's pilot initiates a digital request for a taxi clearance to the assigned runway. Once the TODDS prototypes receive the request, the DCI points to the left and appears in a light blue color to indicate a pending request from the pilot to the controller (see Figure 32).



Figure 32. The DCI indicates on the ground controller position a pending pilot request for a D-Taxi clearance in the Integrated (left) and P-S (right) TODDS.

The controller can select the aircraft's FDE or data block, and the pilot's request will appear in the readout area (see Figure 33).

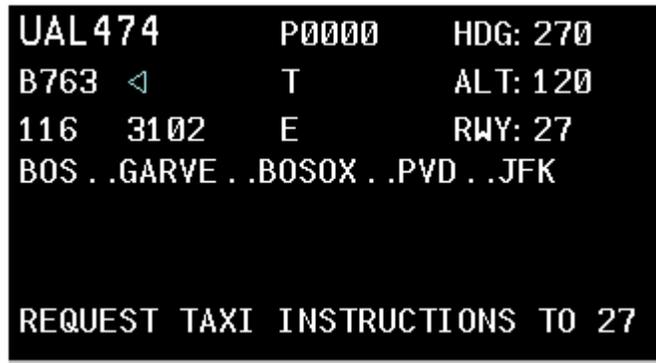


Figure 33. The readout area displays a digital request for a taxi clearance.

After reviewing the pilot's request, the controller can either grant the request or defer the request until later. To defer a pilot's request, the controller simply deselects the aircraft's FDE or data block and the TODDS sends an acknowledgment or standby message to the pilot. A D-Taxi request that the controller has viewed but decided to act upon later appears as a DCI that is an upright triangle highlighted in light blue (see Figure 34).



Figure 34. A DCI in the Integrated (left) and P-S (right) TODDS, indicating that the controller has received and acknowledged the pilots request but has deferred it until later.

To grant a pilot's request, the controller can issue a predetermined D-Taxi clearance by selecting the D-Taxi button located on the TODDS interface (see Figure 35). The D-Taxi button becomes active (displays with white border and text) when the controller selects an FDE or data block for an aircraft that is capable of digital communications. The D-Taxi cancel button becomes active (displays with white border and text) when the controller selects an FDE or data block for an aircraft that has already received or is in the process of receiving a D-Taxi clearance.



Figure 35. Inactive (left) and active (right) D-Taxi and Cancel buttons on the TODDS.

Based on the aircraft's current location (i.e., ramp spot) and runway assignment, the TODDS sends a D-Taxi clearance to the requesting pilot. The D-Taxi clearance includes the current ATIS code, turn-by-turn taxi instructions, hold short instructions, and the next frequency to contact after completing the entire taxi instruction. Currently, there is no mechanism in the TODDS for constructing a random route. The DCI indicates that the controller has sent a D-Taxi clearance to the pilot by pointing to the right and highlighting in light blue (see Figure 36).



Figure 36. The DCI on the Integrated (left) and P-S (right) TODDS, indicating that the controller sent a D-Taxi clearance to the pilot and is pending acceptance.

If the pilot rejects the D-Taxi clearance or the digital communication fails, the DCI points to the right and appears highlighted in red (see Figure 37). The TODDS will also reject a D-Taxi clearance if the clearance contains a closed taxiway or runway. Selecting the FDE or data block of an aircraft that has rejected a D-Taxi clearance opens the readout area and displays the reason for the rejection. The readout area will indicate DATA COMM REJECTED if the pilot refuses the clearance, DATA COMM TIMEOUT if the message times out, or DATA COMM FAILURE if the data communication equipment fails. The controller can address a rejected or failed D-Taxi clearance by either reissuing the clearance or establishing voice contact with the pilot.

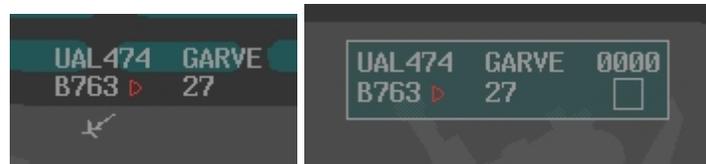


Figure 37. The DCI on the Integrated (left) and P-S (right) TODDS, indicating that the pilot has rejected the D-Taxi clearance or the digital communications has failed.

If the pilot accepts the D-Taxi clearance, the DCI appears as a circle and the TODDS automatically acknowledges the ATIS Update indicator box on the aircraft's FDE. If the clearance includes hold short instructions, the TODDS automatically places a Hold Short indicator on the aircraft's data block (see Figure 38).



Figure 38. The DCI on the Integrated (left) and P-S (right) TODDS, indicating that the pilot has accepted the D-Taxi clearance and will comply with all instructions including holding short of the active runway.

The controller can review a D-Taxi clearance for an aircraft by selecting the aircraft FDE or data block, and the clearance will appear in the readout area (see Figure 39). As the readout area shows, the D-Taxi clearance includes the current ATIS code, turn-by-turn taxi instructions, hold short instructions, and the next frequency to contact after completing the taxi clearance.

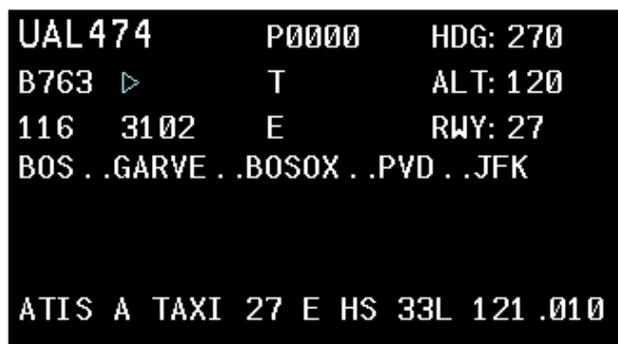


Figure 39. The readout area showing the D-Taxi clearance.

Once the pilot has accepted the D-Taxi clearance, the controller then establishes radio contact with the aircraft and instructs the pilot to execute the clearance with a simple command such as *begin taxi*. Establishing radio contact ensures that voice communication is operational in case the controller must provide immediate instructions to the pilot (e.g., stop). Establishing radio contact also allows the controller to maintain positive aircraft control and ensures that the pilot will begin the taxi procedure in the timely manner that accommodates the planned flow of surface traffic. Without positive control, it would be impossible for the controller to know when the pilot would begin the taxi procedure because of the variable delay in transmitting, reviewing, accepting, and acting upon the D-Taxi clearance. This lack of positive control would reduce the efficiency of surface movements and eliminate the controller's ability to plan and execute departure sequences.¹ The controller moves the FDE from the pending bay to the outbound bay after issuing the resume taxi clearance, and the TODDS automatically assigns a taxi clearance time to the aircraft.

¹ We devised our own D-Taxi clearance procedures based on SME and sponsor input because no established procedures existed at the time of our prototype design.

The controller can cancel a D-Taxi clearance at anytime by selecting an aircraft's FDE or data block and then selecting the Cancel button. The DCI will return to its neutral state indicating that data communication is available, as shown in Figure 31. The D-Taxi Cancel button is available only when the controller selects an FDE or data block associated with an aircraft that is in the process of receiving or has already received a D-Taxi clearance.

3.5 Integrated TODDS – Taxi Conformance Monitoring

The ability to issue D-Taxi clearances also enables taxi conformance monitoring at airports that have a surface surveillance capability. Once the controller issues a D-Taxi clearance, that information could propagate throughout the NAS, and surface surveillance technology such as ASDE-X could monitor an aircraft's movement to ensure compliance. The Integrated TODDS could alert controllers about an aircraft turning onto a wrong or closed taxiway or runway. Such a taxi conformance monitoring system may have mitigated the crash at Lexington, Kentucky, on August 27, 2006, (NTSB Identification: DCA06MA064; NTSB, 2007) and numerous other incursions and accidents that have occurred due to pilots making a wrong turn on the airport surface.

We implemented taxi conformance monitoring with the Integrated TODDS prototype to take advantage of the D-Taxi clearance capability. The taxi conformance monitoring function is fairly simple in that TODDS knows what route an aircraft that has received a D-Taxi clearance is supposed to travel, and it can compare that route to the actual route traveled. If an aircraft takes an unexpected turn or otherwise deviates from its D-Taxi clearance, the Integrated TODDS notifies both the ground and local controllers by flashing the aircraft's data block and FDE text. The data block and FDE text flashes between red and its current ownership color and continues to flash until a controller acknowledges it. A controller can acknowledge a flashing data block from either the ground or local controller position by selecting the aircraft's FDE or data block. Once acknowledged, the FDE text and data block remain red until the aircraft returns to conformance or until a controller cancels the D-Taxi clearance, as previously described. Figure 40 shows an aircraft's FDE and data block that the TODDS has identified as not being in conformance with an accepted D-Taxi clearance.



Figure 40. An FDE and data block highlighted in red, indicating that the aircraft is not conforming to the D-Taxi clearance.

4. SUMMARY AND CONCLUSION

The results from the usability test (Truitt & Muldoon, 2007) provided a number of insights into the initial design concepts of the EFDIs, which is now known as the TODDS. We redesigned a number of the GUI elements, such as the ATIS Update indicator and the expired timers, based on the usability test results. The usability test participants also provided information that led to enhancements of the initial design, such as highlighting an aircraft's data block and FDE when the aircraft is moving on or across a runway surface and providing the ability to add a Hold Short indicator.

The usability test also pointed out the need for more touchscreen training. Just as the computer mouse was once a new input device that required some learning to use effectively, despite its intuitive nature, touchscreens also require some learning because people use them relatively infrequently in today's society. Most people are familiar with the automated teller machine kiosk and other similar touchscreen applications, but people almost never experience other actions such as dragging an object across a screen with their fingertip. Therefore, we recommend that users receive sufficient touchscreen training before using the TODDS. We are currently developing a touchscreen training protocol that will provide users with multiple practice trials on the basic touchscreen actions needed to successfully use the TODDS. We are also interested to know *how* people learn to use touchscreens over time and *how* their performance improves with practice. Although published literature has some information on touchscreen design and usage (e.g., Beringer & Peterson, 1985; Pickering, 1986; Potter, Weldon, & Shneiderman, 1988), literature on touchscreen training is virtually non-existent.

In addition to refining the usability of the initial design, we added a number of new features to the TODDS. The new features include integrated weather information, D-Taxi out clearances, taxi conformance monitoring, an indicator for wake turbulence separation, and indicators for closed runways and taxiway segments. These new features increase the functionality of TODDS beyond mere flight data management and provide ATCT controllers with new tools and methods to help them communicate, coordinate, and reduce their cognitive and physical taskload.

The TODDS prototype designs should also help to reduce the risk of runway incursions and ease the flow of surface operations in the future. The Integrated TODDS prototype may also be an enabling technology for the SNT concept. To test these claims, we seek to conduct further empirical studies of the TODDS prototypes to see how they compare to current operations both with and without surface surveillance.

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Acronyms

| | |
|---------|---|
| 4-D | Four-Dimensional |
| ASDE-X | Airport Surface Detection Equipment – Model X |
| ATCT | Airport Traffic Control Tower |
| ATIS | Automated Terminal Information Service |
| DCI | Digital Data Communications Indicator |
| D-Taxi | Digital Taxi |
| EDCT | Expected Departure Clearance Time |
| EFDI | Electronic Flight Data Interface |
| FAA | Federal Aviation Administration |
| FDE | Flight Data Element |
| FPS | Flight Progress Strip |
| GUI | Graphical User Interface |
| JPDO | Joint Planning and Development Office |
| NAS | National Airspace System |
| NextGen | Next Generation Air Transportation System |
| NOTAM | Notice to Airmen |
| NTSB | National Transportation Safety Board |
| P-S | Perceptual-Spatial |
| RVR | Runway Visual Range |
| SME | Subject Matter Expert |
| SNT | Staffed NextGen Tower |
| SWIM | System Wide Information Management |
| TIPH | Taxi-into-Position-and-Hold |
| TODDS | Tower Operations Digital Data System |