3.22 DISTRIBUTION OF INTEGRATED TERMINAL WEATHER SYSTEM (ITWS) PRODUCTS USING WEB TECHNOLOGY *

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1. INTRODUCTION

The Integrated Terminal Weather System (ITWS) (Evans and Ducot, 1994) is a capital investment of the Federal Aviation Administration (FAA) to provide a fully-automated, integrated terminal aviation weather information system that will improve the safety, efficiency, and capacity of major terminals. The ITWS acquires data from FAA and National Weather Service sensors as well as from aircraft in flight within the terminal area. Demonstration systems are being operated by the Massachusetts Institute of Technology's Lincoln Laboratory (MIT/LL) Weather Sensing Group at four airport terminal areas: New York, NY; Orlando, FL; Memphis, TN; and Dallas/Ft. Worth, TX. Real-time graphical weather information from the ITWS demonstration systems is relayed to primary users (airport towers, en route centers, TRACONS, the Command Center, and major airlines, etc.) via a situation display (SD) that consists of a Sun workstation and a dedicated data line to the ITWS site.

For users who do not have access to a fully operational SD or who want additional flexibility for accessing the ITWS information, MIT/LL operates a demonstration ITWS web server that provides the information for viewing with commercial-off-the-shelf (COTS) web browsers over the Internet and via the Collaborative Decision Making Network (CDMnet)[1].

This distribution of ITWS products has provided shared situational awareness between widely separated users. By sharing a common view of the same operational environment, controllers, dispatchers and other aviation decision makers and stakeholders have been better able to understand and coordinate the decisions that affect air traffic in the terminal area and surrounding en route airspace. In particular, by having up-to-the-minute weather information readily available to airline dispatch, safety during hazardous weather in the terminal area has been improved on a number of occasions at the ITWS demonstration sites (Evans, 2000).

With the upcoming deployment of the ITWS as an operational FAA system to 44 major airports, a priority for the FAA is the distribution of the ITWS information from the production systems to airline dispatch and other non-FAA users. The operational ITWS is not designed to support SDs at the major airlines. Hence, distribution of ITWS information via a mechanism such as the Internet and the CDMnet is essential if the safety and coordination benefits achieved with the ITWS demonstration systems are to be obtained with the production ITWS. Because many airlines do not allow Internet access at all locations within the dispatch office, the current plan is to use CDMnet as the primary vehicle for ITWS data distribution to non-FAA users. However, to increase the availability of ITWS information to the broader ITWS user community, efforts are underway to make the data available on the Internet as well. Use of the Internet and CDMnet could also facilitate low-cost distribution of the ITWS information to additional FAA and non-FAA users alike.

This paper describes the evolution of the ITWS demonstration web server, discusses the design of the web server and data processing, details how to access the web page and what products are currently available, presents some access statistics and current airline users, and discusses some future work which will allow for wide distribution of the production ITWS information.

2. WEB SERVER DEVELOPMENT

The initial version of a prototype ITWS web page was developed in late 1997 to provide ITWS information to airlines that did not have a fully operational SD. Since that time, the server and data processing have undergone two major upgrades: the first was done in April 1999, and the second was completed in April 2000. The first upgrade improved the design, maintainability and accessibility of the site by converting the static HTML pages to Perl/CGI scripts. Additionally, access to the site was improved through a change from a computer address (IP) based access to a user account system. The most recent upgrade added the ability to view data from the ITWS Storm Cell Information (SCI) and Terminal Winds products, improved the overall design, and further increased the distribution potential of the ITWS data by adding a duplicate server on the CDMnet. These most recent upgrades also included the addition of 15 nautical mile (nm) range imagery with a two-minute update rate and a pan/zoom interface.

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[1] CDMnet is the data distribution infrastructure for the Collaborative Decision Making (CDM) program. It is used for exchanging data between certain airline operating centers (AOCs) and the FAA. The CDM data distribution system has a hub and spoke architecture, with the hub being implemented at the Volpe Center. AOCs connect to the CDM hub using communications capabilities provided by third-party vendors (such as ARINC).

3. DESIGN CRITERIA

The design philosophy used in the development of the ITWS web page has been to keep the interface simple and streamlined. The primary characteristic that makes the ITWS web site different from some aviation weather sites is that the ITWS site is a real-time weather display, not a briefing tool. Thus, the maximum benefit of the site in terms of situational awareness is realized when the user stays connected over the entire period during which the weather situation within the terminal area is evolving. Given the real-time nature of the site, the most important design criterion is that all the applications and data on the web site update frequently and automatically. The page must also load quickly when first accessed, as some users simply check the site once for current weather and check back from time to time. In addition, the data must be as close to real-time as possible; the age of the data must be reported, and the design should allow for multiple sites and ranges to be displayed at the same time for efficient monitoring.

4. DATA PROCESSING AND DISTRIBUTION

Data processing is an important part of any real-time system, as the time between collection of the data and the time the data are available to the user must be kept to a minimum. A somewhat simplified view of the web-based distribution of ITWS data from the demonstration systems is shown in Figure 1. The data processing spans three local networks: the MIT/LL real-time network, the MIT/LL FAA isolated/secure network, and the CDMnet. The connection from MIT/LL to the CDMnet is through the CDM datagate, which is hosted by the Volpe National Transportation Systems Center (Volpe) in Cambridge, MA.

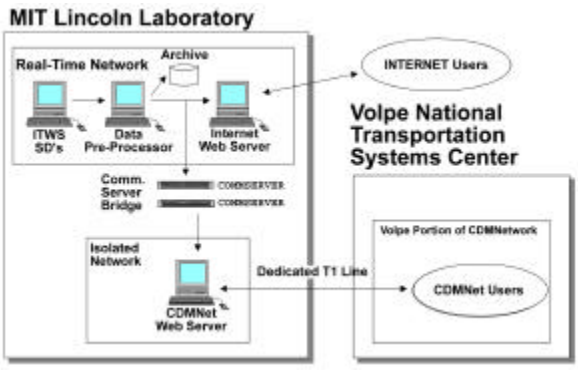

Figure 1. Configuration for ITWS Web Data Processing.

On the ITWS SD computer there are two software processes: (1) the SD software which creates the display, and (2) the SD snapshot process which captures configured SD screen images as GIF images and data at set ranges and a pre-set frequency. Once the data are captured, the image of the SD, along with the selected product data, is then distributed over the local network to an intermediate processing computer. This computer scales the images to various sizes and creates short (six frame) movies of the images. This machine processes the images immediately and sends them to the web servers. The data for the Internet web server are distributed directly across the local network, and the data for the CDMnet web server are passed through a pair of serial communication servers.

These servers act as a one-way secure bridge between the MIT/LL real-time network, which is connected to the Internet, and the CDMnet, which is not. The CDMnet users can then access the web server through the Volpe portion of the CDMnet via a high bandwidth data line (T1) which connects the isolated network at MIT/LL with the rest of the CDMnet. The delay incurred by the transfer and processing of the real-time data is less than one minute for the Internet server, while the delay for the CDMnet server is approximately 90 seconds due to the additional translation required to send data over the relatively low bandwidth communication servers.

5. ACCESS AND USE

Access is controlled through user accounts that are available to any aviation user with a need for real-time terminal weather information at the demonstration sites. The address of the web site is http://www.wx.ll.mit.edu/itws, and requests for user accounts can be sent to wxwebmaster@ll.mit.edu. Access to GIF images is also available via FTP, which allows for automated access to the data. Additional setup is required for this type of access; more information can be obtained by sending email to the address above.

When the page is first accessed, the view is of thumbnail-size images of the TRACON range ITWS display at the four ITWS demonstration sites as seen in Figure 2. Above each image are two colored bars which show the current status of the image or movie and SCI

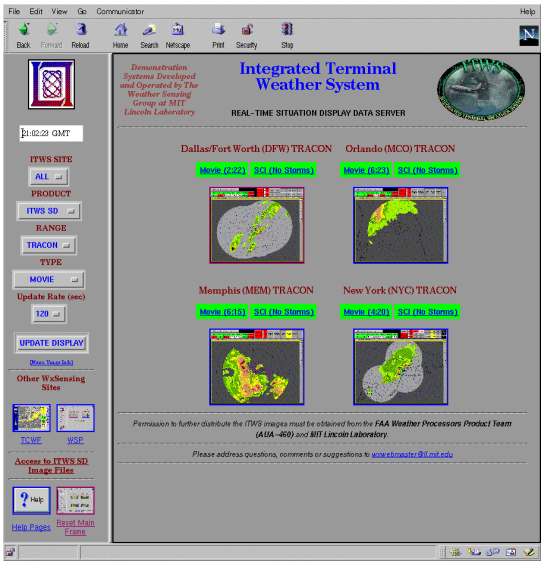

Figure 2. The ITWS Web Page.

data. The background color of each of the status bars indicates the current availability of the data. Green indicates that the data are available and up to date, yellow indicates that the product is available but the age

of the data is nearing the timeout threshold, and red warns that the product is not available. In addition, the image status bar contains text indicating the age of the data in minutes and seconds, and the SCI status indicates the number of currently tracked storms in the range being displayed. If there are no storms, the text displayed reads 'no storms'. For each of these status bars, additional status information is displayed when the text in the status box is highlighted with the mouse.

From this initial page, the user either can go directly to the TRACON view for a particular site by clicking on the thumbnail image or change to another combination of ranges and sites by selecting the desired menu settings on the left-hand side of the screen. Links at the bottom of the menu can take the user to other MIT/LL web pages which provide weather information for the airport terminal area. The two other web sites currently available are drawn from the MIT/LL-operated demonstration of the Weather Systems Processor (WSP)(Weber and Stone, 1995) and the Terminal Convective Weather Forecast (TCWF) (Hallowell, et. al, 1999) experiments. The WSP demonstration systems operate at Austin, TX and Albuqueque, NM. The TCWF currently operates at each of the demonstration ITWS sites and provides up to 60-minute forecasts of position and strength of convective weather. These sites, along with the ITWS site, are all available with the same user account. A link also will be available for the Medium Intensity Airport Weather System (MIAWS) when it becomes operational. That system is currently in development by MIT/LL. A demonstration system will be fielded at Jackson, MS later this year.

6. AVAILABLE PRODUCTS

With the most recent upgrade, the majority of the ITWS SD products (with the exception of the runway configuration, ASR AP regions, the 5 and 100 nmi product suites, and runway-specific alert products) are now available on the web site. The web site displays real-time images and movies of the ITWS SD at three ranges: airport (15 nm), TRACON (50-90 nm depending on site) and regional (200 nm). The update rates of these three ranges are two, four, and eight minutes, respectively. The ITWS products available on the web site are as follows:

- ASR-9 precipitation with anomalous propagation (false echoes) removed on 15 nm and TRACON range
- NEXRAD precipitation on 200 nm range
- Storm motion arrows and storm extrapolated position indicators for up to five areas of VIP level 3 and higher precipitation superimposed on ASR-9 and NEXRAD precipitation maps
- Microbursts detections*
- Gust front detections and forecast positions*
- Gust front wind shift estimates*
- Tornado detections
- Microburst alert panel
- Wind shear alert panel
- Lightning alert panel
- Tornado alert panel
- Anomalous propagation alert panel
- Gust front alert panel
- Gust front time to impact
- Terminal Winds via a separate display window
- Storm cell information (echo tops, lightning, hail and severe storm circulation information) through pop-up windows on the ITWS SD image.

All of these products, except Storm Cell Information and Terminal Winds, are viewable on the ITWS SD image without any interaction needed. Terminal Winds is displayed through a separate window that is activated from the menu, and Storm Cell Information is displayed as pop-up windows over the ITWS SD image. These products are recent additions to the ITWS web site and are described below. For a detailed description of the other ITWS products, refer to "The Integrated Terminal Weather System (ITWS)" (Evans and Ducot, 1994).

The SCI product provides a textual description of storm attributes that cannot be deduced from the ITWS precipitation products alone. The SCI algorithm reports on the detection of mesocyclones (severe storm circulations), severe hail, lightning, and provides echo top heights in hundreds of feet. If the components of the products are unavailable, this is indicated (ex: Hail: Unavailable). This product is produced for storm cells of precipitation intensity level 3 or greater. The ITWS SCI data are visible on the web page via pop-up windows overlaid on the ITWS SD images. Due to the nature of the SCI data, the information cannot be displayed effectively on a movie; thus, it is available only on the images. The SCI data window becomes visible as the user moves the mouse over an active storm cell. This provides functionality that is similar to the actual ITWS SD, where the SCI is displayed by clicking on the active storm cell. An example of the ITWS web SCI product is shown in Figure 3.

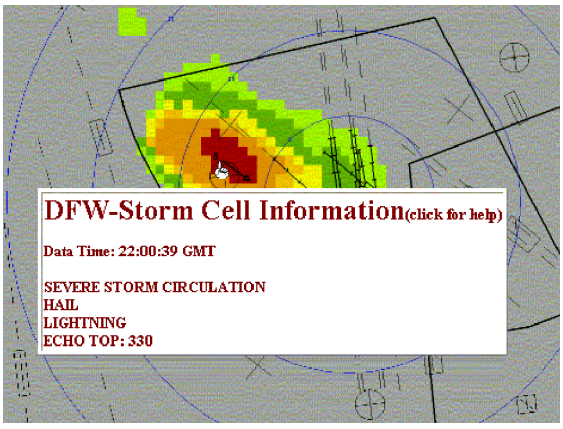

Figure 3. Example of ITWS Web Storm Cell Information.

* Only on 15 nm and TRACON ranges

The ITWS Terminal Winds product provides frequently updated estimates (every five minutes) of the horizontal wind at various altitudes for points of interest to ATC users (e.g., at the arrival and departure gates and when turning on to final approach). The terminal winds data are accessed on the web site by clicking on the 'TermWind' button which is available on the left menu when data from a single site are being displayed. Clicking on the button opens up a new browser window containing the Terminal Winds profiles in the same format used with the actual ITWS SD. Figure 4 shows the Terminal Winds data window for Memphis (MEM). The data update automatically from the server and the status of the data is shown as the background color of the status bar below the title, along with the age of the data in minutes and seconds in parentheses. The background of the status bar uses the same color convention as in the main image window, described in Section 5.

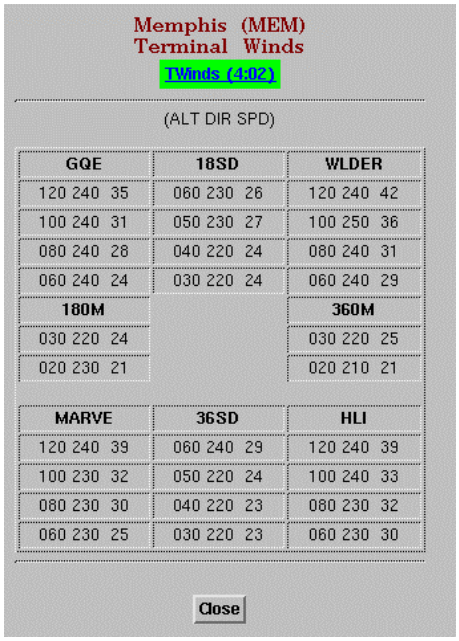

Figure 4. Example of ITWS web Terminal Winds.

A zoom window is available as well. This utility allows the user to zoom in on, and pan around, the ITWS SD image to allow more detailed viewing. Figure 5 shows the Zoom window for Dallas/Ft. Worth (DFW). The image can be zoomed in or out by using the zoom control buttons, and the zoom area can be panned around by clicking on a direction in the compass icon in the upper left corner.

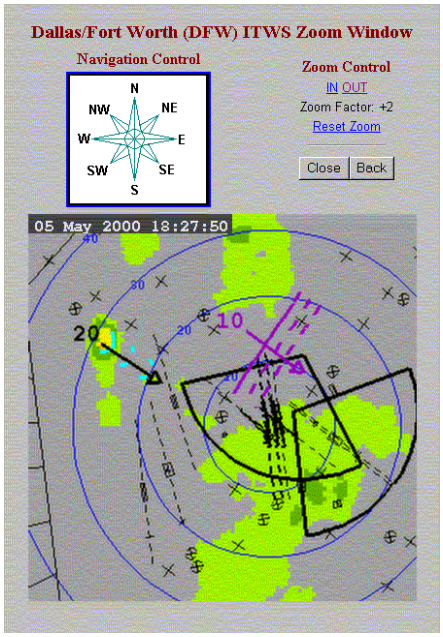

Figure 5. Example of ITWS Web Zoom window.

7. USERS AND ACCESS STATISTICS

A complete list of airlines that currently have access to the ITWS web site is shown in Table 1. Currently, most major airlines are using the ITWS web page, although the amount of use is highly dependent on the extent of Internet connectivity in the airline dispatch office and the extent of dispatch access to a fully functional SD. For example, Table 2 lists the access use for the period of May to October 1999, which roughly represents the summer convective season (user specific statistics were not available prior to the April 1999 upgrade). It is clearly seen that Delta and Delta Express had a much higher usage than all others. This can be attributed to several factors:

1. Delta has a fully functional SD; however, it is located in the meteorology office and cannot be seen from the Delta dispatch positions;
2. All dispatchers have Internet access at their positions;
3. There are two operations centers which are using the web site: Atlanta, GA and the Delta Express operations center at the hub in Orlando, FL;
4. Delta operates many flights in and out of Dallas/Ft. Worth and the New York area, and the Delta Express hub is Orlando, FL, all of which are ITWS demonstration sites.

Table 1.
Airlines using ITWS Web Page.

Nationwide Carriers	Regional Carriers
AirTran American American Trans Air Continental Delta/Delta Express Federal Express Northwest Southwest TWA United United Parcel Service USAirways	Business Express Airlines Comair Crow Air Midwest Express National Airlines Northwest Airlink

Southwest and American airlines' less frequent use of the web site can be explained by the fact that they access the ITWS GIF images via automated FTP and distribute them internally on their own display system, thus reducing the need to look at the ITWS web site. Some airlines (American and Fed Ex) display the ITWS SD for their hub on a large screen at their operations center. The other airlines listed were occasional users who looked at the web site in quick hits during periods of weather but did not keep the display up for long periods of time.

Table 2.
Airline usage of the ITWS web page for the period May through October, 1999. The * denotes airlines which also have a fully functional ITWS SD. The hourly usage is estimated from the number of accesses based upon an average update rate.

Airline	Average Monthly Hits	Average Monthly Usage (hrs)
American*	559	18.5
AirTran	169	5.7
Continental *	163	5.5
Delta/Delta Express *	11517	383.8
Federal Express *	326	10.8
Midwest Express	175	5.8
National	39	1.3
Northwest *	45	1.5
Southwest *	1924	64.2
TWA	384	12.8
United *	193	6.5
United Parcel Service	192	6.4
USAirways	372	12.5

8. FUTURE DEVELOPMENTS

Requirements are currently being defined for a production version of an ITWS data server that will include not only browser-viewable images and data, as currently available, but also the product data streams that drive the production SD. The availability of the product data will allow those airlines that desire it to incorporate the ITWS products into their own dispatch information display systems. The proposed server will distribute data over the Internet and CDMnet, although the extent of availability of the different data types has not been fully defined at this time.

The development of this production ITWS data distribution system is planned as a collaboration between the FAA, MIT/LL, and Volpe. It is anticipated that the web interface and image generation and data capture tools will rely heavily on the demonstration web server discussed above. Volpe will host the server, as they currently have high-capacity connectivity to the Internet, the CDMnet, and to the majority of the TRACONS where ITWS will be installed.

A challenge exists in developing browser-viewable images for this production data server in that a scaleable application must be developed to generate GIF images directly from multiple production ITWS product data feeds as opposed to using screen dumps to generate them.

Another challenge will be to develop an effective web interface that will allow the user to quickly and easily navigate through the 44 airport-specific presentations of the ITWS data to determine which airports of interest are being impacted by weather so that they can be monitored. This interface must allow for some level of customization for individual users, while retaining the ability to view data from other ITWS sites quickly.

9. CONCLUSIONS

With the upcoming deployment of ITWS as an operational FAA system, there is a need to continue to expand the availability of ITWS products to non-FAA users. This could increase safety by providing the users with awareness of severe weather in the terminal area and could improve efficiency by increasing the amount of situational awareness and coordination between the air traffic decision makers.

The use of web technology has greatly expanded the availability of the critically needed terminal weather data provided by the ITWS system and has allowed a wide variety of users within the aviation community to experience the benefits of having this information available in real time. These demonstrated benefits include allowing widely separated users to share the same situational awareness during hazardous weather by providing them with the same display, allowing optimal utilization of collaborative decision-making techniques. Airlines have come to depend on the availability of the ITWS products via dedicated SDs, the Internet and CDMnet, and it is imperative that these capabilities remain when the production ITWS system is deployed.

The FAA recognizes this need and is currently working to define a set of requirements for which a production ITWS data server will be developed. The demonstration system described in this paper will clearly be a key element of the requirements specification

process and an important presursor to the implemention of an operational capability.

The goal is to have this production data server in place as the first production ITWS sites come on line in early 2001. This production server would then take over the distribution of ITWS information over the Internet and CDMnet as the demonstration ITWS systems are replaced with production versions. The end result of this will be increased safety and efficiency for the aviation users within the terminal area and adjacent en route airspace.

10. APPENDIX: TECHNICAL DESCRIPTION OF STORM CELL INFORMATION DISPLAY TECHNIQUE

The SCI display uses an interesting combination of web technology. It is created by a Perl/CGI script which distributes HTML and embedded JavaScript, dynamic HTML, and image maps with current data in real time. This technique is described here.

The SCI data are saved from the SD product data feed in a text file as a list of active storm cells, with the storm cell information text and the cell coordinates in nautical miles (nm) north and east of the airport center. When the client browser requests the ITWS SD page from the server, a Perl/CGI script reads this data file. On all multiple-range and multiple-site displays the script simply reads the number of storms and the valid time information for display in the status box. When a single site and range image is requested, however, the full SCI data set is read for display. In this situation, the web server script takes this text file and converts the coordinates in nm to pixel offset coordinates within the ITWS SD image. It first saves the SCI data in the HTML output to the browser by storing the data for each tracked cell into dynamic HTML 'span' tags, which are mapped to individual cascading style sheet elements with the visibility set to 'hidden'. The pixel offsets are then used by the server script to create an image map of the ITWS SD image, with each storm cell as an active area. Each area is then activated using a JavaScript 'onMouseOver' event handler which allows the SCI data box to appear by changing the value of the visibility setting to 'visible'. This allows for the display of data in pop-up windows without the need to click on the storm cell as in the actual ITWS SD.

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