2.3 FEEDBACK FROM THE USERS OF COMMISSIONED TDWR SYSTEMS

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1. INTRODUCTION* †

The primary mission of the Terminal Doppler Weather Radar (TDWR) system is to detect thunderstorm-related wind shears and microbursts that are potentially hazardous to aircraft during landing and takeoff operations (e.g., within three nautical miles on final approach and within two nautical miles on departure). The sources of these wind **shears** are microbursts and gust fronts. The mechanism by which these wind shears are provided to Air Traffic Controllers is the Ribbon Display Terminal.

A secondary mission of the TDWR system is to support traffic management by the detection of precipitation and detection and forecast of gust-front-induced wind **shift**. This information is provided to the Air Traffic managers (Supervisors and Traffic Management Coordinators) via the Situation Display.

The TDWR Program Office tasked Massachusetts Institute of Technology Lincoln Laboratory to survey the first five commissioned TDWR sites in order to assess how well the system was meeting its mission goals and to measure user (Air Traffic Controllers and air traffic managers such as Supervisors, Traffic Management Coordinators, etc.) benefits achieved through deployment of the TDWR. A list of candidate questions was prepared (Appendix A). Site visits commenced on 28 November 1995 and ended 25 January 1996.

At each site, interviews began with a tour of the Air Traffic Control Tower. Questions regarding airport configuration, number of operations, and weather impact on operations were asked to provide a context for controller and traffic manager interviews. Users who acted in the capacity of controller were asked questions regarding their perceptions of the accuracy of the Ribbon Display Terminal messages and their views of the impact (if any) on the effectiveness with which they performed their duties. Users who performed the duties of traffic managers (Controllers-in-Charge, Supervisors, Traffic Management Coordinators) were asked questions about the operational benefits of the products on the Situation Display.

After the interview process was completed, the benefits estimates claimed for the TDWR system were revisited.

2. PRIMARY TDWR MISSION: SAFETY

The Ribbon Display Terminal provides text messages (wind shear and microburst) to controllers for relay to approaching and departing aircraft. The users were asked their perceptions on the accuracy of the messages (i.e., When available, did pilot reports tend to agree with the Ribbon Display Terminal message as issued?). The users were unable to comment on the accuracy of microburst messages. Pilots tended not to land or depart when microburst messages were issued. As a result, there were no pilot reports to confirm the TDWR messages.

A Tower Supervisor related an anecdote about an afternoon when there was an LLWAS alert associated with a storm on the end of the runway. The pilot of a fully-loaded heavy jet was debating whether or not to take off when the TDWR issued a 60 knot loss microburst alert. The pilot chose to delay the aircraft's departure until after the storm either moved or dissipated. The pilot thanked the Air Traffic for the warning saying that his aircraft would not have been able to cope with a 60 knot loss on takeoff.

Another Supervisor cited a situation during which a pilot was given a wind shear message for a 25 knot loss on 1-mile departure. The pilot used full throttle and kept the aircraft's nose up. The pilot subsequently called the controller and said "Thanks, I wouldn't have recovered from a 25kt loss without the alert."

In general, the users perceived that the wind shear messages were accurate; when pilot reports (PIREPs) were given the PIREPs generally confirmed the wind shear message. Thus, the TDWR system is meeting its primary mission goal of enhancing safety by detecting hazardous thunderstorm-induced wind shears.

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3. SECONDARY TDWR MISSION: PLANNING

The TDWR provides products on the Situation Display that can be used to support air traffic planning. The gust front product and wind shift estimates on the Situation Display were developed to aid in anticipating runway changes due to thunderstorm-induced wind shifts. It was expected that air traffic managers would use this product to taxi aircraft to the appropriate end of the runway to take advantage of the anticipated wind shift and resulting runway reconfiguration. In addition, flying time of arriving aircraft would be reduced. The presence of the precipitation and graphical microburst product on the Situation Display would provide the users with situational awareness.

3.1 Gust Front Product

One facility particularly liked the gust front product. There was a favorable impression of the performance of the product (detection and forecast). Users generally could not comment on the performance of the wind shift estimate as they had never really assessed the product. Apparently it was sufficient to know that a gust front was present. One Supervisor claimed that he could time the arrival of the gust front at the airport "to the aircraft." Users did not recall misses and were not concerned about the few false alarms they had observed. The false alarms generally occurred when there was no convective weather in the area and thus were obvious false detections. It is likely that the acceptance of the gust front product at this facility is due to reasonably good performance of the algorithm in that weather regime and to realistic expectations of the product by the users.

At the other facilities however, the users expressed dissatisfaction with the gust front product. Numerous controllers mentioned that gust fronts impact the airport without any detection by the TDWR. They described these "misses" under several weather conditions; gust fronts that travel along the leading edge of a thunderstorm and wind shift lines that come through on cloud-free days. Users noted that on many occasions, gust fronts approaching the airport have disappeared from the display, which caused the users to assume that the wind shift line dissipated. Then the front crosses the airport and catches the users unprepared. These anecdotes probably describe gust front detections that are dropped temporarily because of poor viewing angle.

Some users commented that the detections that do cross the airport seem to be reasonably accurate and that some users sometimes employ the gust front product to anticipate changes in runway configuration. Rather than trust the gust front product outright, the users tended to use additional observations from outlying airports to corroborate the gust front product. If the winds shifted at the outlying airports then the users acted in anticipation of the gust front passage. The tower sometimes held departing aircraft in the gate area and they occasionally taxied aircraft to the upwind end of the runway in anticipation of the wind shift. Some users said that they do not have enough confidence in the product to act in anticipation of gust front passage.

In a few facilities, the gust front product was being used as a surrogate for storm motion. At those facilities, gust fronts tend to be associated with line storms and tend to lie along the leading edge of the storm. In this case, gust front motion is not greatly different from storm motion and reasonable approximations to storm motion. Two supervisors who were staunch supporters of the product admitted that they would give up the gust front product for a true storm motion product.

3.2 Precipitation Product

The precipitation product on the Situation Display was well-liked by the users. The color display made the product easy to interpret and was preferred to the ASR-9 monochrome weather presentation. Users perceived that the intensity level and location of the precipitation as indicated by the TDWR were accurate, especially when compared to the ASR-9 data which were often contaminated by anomalous propagation. Users cited many scenarios when the precipitation product is used to plan traffic flows: anticipating the closing and opening of gates and weather impact at the airport, identifying regions pilots are likely to avoid, etc. Some users had seen TDWR attenuation but do not consider this an impediment to their jobs. Under those circumstances, the weather near the airport was of greater concern than the attenuated weather.

One user reported false echoes in the TDWR precipitation product within 15 nm. One supervisor would like to see the coverage of the precipitation product extended to longer ranges.

One supervisor commented that the TDWR appeared to be more accurate within 15 nm and ASR-9 was more accurate outside 15nm. One user commented that the update rate was slow compared to the ASR-9.

3.3 Microburst Product

Some traffic managers use the presence of microbursts on the Situation Display as an indication of intensity of the weather. Some users commented that when they see microbursts associated with weather moving toward the airport, it provides a heads-up that microbursts may soon impact the airport.

4. ADDITIONAL OBSERVATIONS

4.1 TDWR Training

The users indicated that the training program focused too much on the Situation Display; describing what would happen to the display when a button was pushed. It provided no background about what the system was designed to do and what its expected performance should be. For example, many respondents indicated that the training was too simplistic and led them to believe that the system was capable of detecting all wind shear, including all wind shift lines and wind shear on days with no thunderstorms. When the TDWR system behaved differently than expected (e.g., by not detecting wind shears on clear, blustery days) the users lost confidence in the system. As a result, the users are not comfortable with the system and do not take full advantage of the products.

Had background information on the TDWR system (such as weather phenomenology, scan strategies, and algorithm performance) been available to the facilities in an easily accessible manner, most users would have taken the opportunity to familiarize themselves with the information outside the formal training program. This would have reduced unrealistic expectations of the system and increased overall user satisfaction. In addition, users often noted that the training was performed well in advance of the commissioning of the system (usually due to delays in the commissioning process). The users indicated that a brief review (such as a short video) would have been useful.

At one facility, controllers related many instances on clear, blustery days when the LLWAS was issuing wind shear messages, pilots were reporting wind shears, and the TDWR was silent. The users believed that the TDWR was missing wind shear events. LLWAS anemometers and landing and departing aircraft do experience blustery, turbulent winds. In the past, LLWAS alarms associated with this phenomenon would probably have been considered nuisance alarms. Pilots might have experienced air speed fluctuations and reported the encounter as turbulence or "bumps." Now pilots are trained to identify and avoid wind shears, resulting in increased awareness. Pilots are now more likely to report wind shear encounters; even encounters with weak shears. In addition, it is suspected that pilots are more likely to categorize any encounter that results in an air speed fluctuation (thermals, turbulence, etc.) as wind shear, thereby confirming the LLWAS "nuisance" alarms. Are these "nuisance" alarms truly nuisance or are they operationally significant wind shears? Do pilots want to be informed of the presence of these conditions?

4.2 *Miscellaneous*

One TRACON supervisor was very enthusiastic about the TDWR. He sometimes read the alerts from the Situation Display to TRACON controllers and asked the TRACON controllers to pass alerts to pilots in the arrival stream. On one occasion when there was a gust front seven miles from the airport, the TRACON controller passed the information to a pilot and the pilot reported moderate turbulence in the vicinity of the gust front.

One controller expressed a wish to move the centerfield wind display, from its present position at the bottom of the Ribbon Display Terminal, to the top of the Ribbon Display Terminal. The same controller expressed a desire for consistency in the notation for calm winds. All other systems use the notation "360 00"; the TDWR uses the word "CALM."

Controllers felt that the requirement to deliver TDWR messages to pilots has resulted in an increase in workload during times when adverse weather is impacting the airport.

Some respondents said that they would like to hear an audible alarm whenever a new ARENA receives a windshear or microburst alert. Under the current system, after an alarm has been acknowledged, the Ribbon Display Terminal does not generate an audible alarm again until all alerts have cleared AND a certain time period elapses (e.g., 15 minutes). The users disagreed about whether they would like to hear an audible alarm for changes in alert magnitude in the same ARENA.

The Denver users had been exposed to a TDWR prototype system for several years at Stapleton International Airport. They are very familiar with the TDWR products, the distinction between LLWAS and TDWR, and the concepts of anemometer-based and radar-based wind shear detection. There are a few substantive differences between suite of products that was offered in the prototype system and those available in the production TDWR. The prototype had a storm motion product and, on the 5 nm range, displayed the LLWAS vectors graphically. Nearly all Denver users indicated that they missed the storm motion and LLWAS vector products and that they were not informed that the products would not be available when they moved to the Denver International Airport.

Several users wanted the runway configurations to be labelled with names rather than numbers. The current method necessitates the use of a "cheat-sheet" near the Situation Display which describes which runways are included on the numbered configurations.

A number of the users believed the wind shift product indicates gust front motion instead of the wind shift estimate.

5. Realization of Safety and Delay Benefits

5.1 *Originally Envisioned Benefits*

5.1.1 Safety Benefits

The TDWR is first and foremost a safety-related radar. Its mission is to detect wind shear near the airport, to ascertain the strength of the shear, and to issue alerts to air traffic controllers. According to the ATC personnel who were interviewed, when the radar is operational the TDWR performed its safety task well. Some users were dissatisfied that the TDWR does not issue alerts for some of the "blustery day" shear events where pilots report gains and losses of 10-20 knots in clear-air conditions. Because the LLWAS is an anemometer-based detection system, it does issue alerts on blustery days. The consistency between the LLWAS alerts and pilot reports is comforting to the air traffic controllers. Those weak, blustery-day events, however, are not generally viewed as hazardous. The TDWR was designed to issue alerts associated with potentially hazardous, thunderstorm-related wind shear events and it does so with high reliability.

5.1.2 Anticipating Runway Changes Due to Gust Fronts

The TDWR deployment studies also listed one category of delay reduction benefit. The gust front product and wind shift estimates on the Situation Display were envisioned to be beneficial in anticipating runway changes due to thunderstorm outflows. The ability to anticipate runway changes would save departing aircraft from taxiing to one end of the runway only to be told to taxi down to the opposite end of the runway because of the wind shift. Arriving aircraft were also envisioned to derive some reduction in flying time. In our estimation, this category is not being fully achieved.

The TDWR gust front product detects approximately 40% of all gust fronts. The algorithm has a difficult time detecting fronts that are radially aligned with the radar. Consequently the algorithm often drops the detection as the front passes over the radar on its way to the airport. As a result of their experiences with missed detections, dropped detections, and false alarms the users do not have a high degree of confidence in the gust front product.

This benefit category could be more fully realized if the Machine Intelligent Gust Front Algorithm (MIGFA; Troxel and Delanoy, 1994) were implemented in the TDWR. MIGFA detects approximately twice as many gust fronts as the TDWR algorithm (Klingle-Wilson, *et al.*, 1996) and it does a better job of maintaining the detections as the fronts become radially aligned with the radar.

5.2 *Recently Identified Benefit Categories*

The Integrated Terminal Weather System (ITWS) Key Decision Point (KDP)-3 benefits study (Rhoda, 1996) lists twenty-nine benefit categories related to the depiction of TRACON weather during thunderstorms. Several categories are applicable for the TDWR program. These benefits can only be fully realized if a storm motion product is added to the TDWR software suite. The categories listed here are related to departure transition areas. Additional benefits accrue to airspace system users (airlines and passengers) from other benefit categories.

5.2.1 Departure Transition Area Management

It is hypothesized that TRACON traffic managers are more affected by weather in the Departure Transition Areas (DTAs) than by weather in the Arrival Transition Areas (ATAs). If the DTAs close, planes begin to stack up in the TRACON airspace and must be managed by TRACON and tower personnel. If ATAs are closed by storms, the aircraft stack up in the en route airspace and are not, for the moment, problematic to the TRACON personnel. This is an oversimplification but seems, to a first order, to be accurate. Hence, as far as benefits to the FAA, only benefit categories related to the management of TRACON and DTA airspace are considered.

5.2.2 DTA Closure/Opening Anticipation

The ability to anticipate when weather will affect DTAs leads to efficient traffic management in the TRACON. Aircraft may be routed to DTAs that are clear of weather or they may be held on the ground until the appropriate DTA is clear of weather. The six-level precipitation depiction on the TDWR Situation Display is easy to interpret and, if combined with a storm motion product, would make it easy for traffic managers to anticipate when storms will affect DTAs. The ability to anticipate weather impacts on DTAs would lead to shorter TRACON flying routes and a less stressful working environment for TRACON controllers.

5.2.3 Runway Changes due to Thunderstorm Impact

If the six-level precipitation product were augmented with a storm motion product, traffic planners would be able to anticipate when storms moving into a final approach path would necessitate a runway change.

5.3 *Quantification of Benefits*

It is estimated that the recently identified benefit categories would result in annual air carrier delay reduction of 2300 hours at the TDWR airports, which would save the airlines and the flying public approximately $5.3 million per year.

These figures are based on the ITWS KDP-3 delay benefit calculations. That study attempted to account for the benefits of the baseline systems. TDWR was assumed to have a storm motion product as well as a six-level precipitation map. These estimates are fairly conservative in that they only account for air carrier delay. Air taxis, general aviation, and military flights were not included in the TDWR calculations.

6. CONCLUSIONS

The TDWR system is accomplishing its primary mission of increasing safety with respect to thunderstorm-induced wind shear conditions.

While every facility visited believes they are better off with the TDWR system than without it. In general, users are comfortable with and trust the microburst and precipitation products. They believe these products are accurate and useful. However, gust fronts product is believed to be inaccurate and untrustworthy.

The users tend to have unrealistic expectations of the performance of the TDWR products. This can be alleviated by providing training materials that support the training specialists' work, such as a short video, short papers (three pages or less) describing the various products, and/or use of a World Wide Web home page that provides answers to frequently asked questions.

The performance of the gust front product should be improved to increase users' confidence and fully realize the potential benefit of the product.

The addition of the storm motion product would result in significant planning benefits.

7. References

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