INFORMATION REQUIREMENTS FOR SUPERVISORY AIR TRAFFIC CONTROLLERS IN SUPPORT OF A WAKE VORTEX DEPARTURE SYSTEM

Gary Lohr, Daniel Williams, Anna Trujillo
NASA Langley Research Center, 24 West Taylor Street, Hampton, VA 23681, USA

Keywords: *WTMD, CSPRs, ATC, wake vortex*

Abstract

Closely Space Parallel Runway (CSPR) configurations are capacity limited for departures due to the requirement to apply wake vortex separation standards from traffic departing on the adjacent parallel runway. To mitigate the effects of this constraint, a concept focusing on wind dependent departure operations has been developed, known as the Wake Turbulence Mitigation for Departures (WTMD). This concept takes advantage of the fact that crosswinds of sufficient velocity blow wakes generated by aircraft departing from the downwind runway away from the upwind runway. Consequently, under certain conditions, wake separations on the upwind runway would not be required based on wakes generated by aircraft on the downwind runway, as is currently the case. It follows that information requirements, and sources for this information, would need to be determined for airport traffic control tower (ATCT) supervisory personnel who would be charged with decisions regarding use of the procedure. To determine the information requirements, data were collected from ATCT supervisors and controller-in-charge qualified individuals at Lambert-St. Louis International Airport (STL) and George Bush Houston Intercontinental Airport (IAH). STL and IAH were chosen as data collection sites based on the implementation of a WTMD prototype system, operating in shadow mode, at these locations. The 17 total subjects (STL: 5, IAH: 12) represented a broad-base of air traffic experience. Results indicted that the following information was required to support the conduct of WTMD operations: current and forecast weather information, current and forecast traffic demand and traffic flow restrictions, and WTMD System status information and alerting. Subjects further indicated that the requisite information is currently available in the tower cab with the exception of the WTMD status and alerting. Subjects were given a demonstration of a display supporting the prototype systems and unanimously stated that the WTMD status information they felt important was represented. Overwhelmingly, subjects felt that approving, monitoring and terminating the WTMD procedure could be integrated into their supervisory workload.

1 Introduction

Current Air Traffic Control (ATC) procedures require additional separation between aircraft arriving or departing in trail of certain aircraft categories out of consideration for the effects of wake turbulence. These standards are contained in the ATC Handbook [1]. Controllers apply these standards regardless of weather conditions, unless the requirements for visual separation are met and appropriate procedures are applied. In many cases, this results in overly-conservative (excessive) spacing compared to what is required to avoid the wake hazard. The adverse effects on airport capacity and, hence, the National Airspace System (NAS) resulting from the applications of current wake turbulence separation standards, are well documented. Efforts have been underway for many years to improve understanding of the wake vortex phenomenon and to characterize the associated hazards. This knowledge may permit reduced separation behind wake generating aircraft and improved capacity [2].

A concept focusing on wind-dependent departure operations has been developed [3]. The current version of this concept is called the Wake Turbulence Mitigation for Departures (WTMD). This concept would be applied to operations at airports with closely spaced parallel runways (CSPR), and takes advantage of the fact that cross winds of sufficient velocity blow wakes generated by "heavy" and B757 category aircraft on the downwind runway away from the upwind runway (Fig. 1).

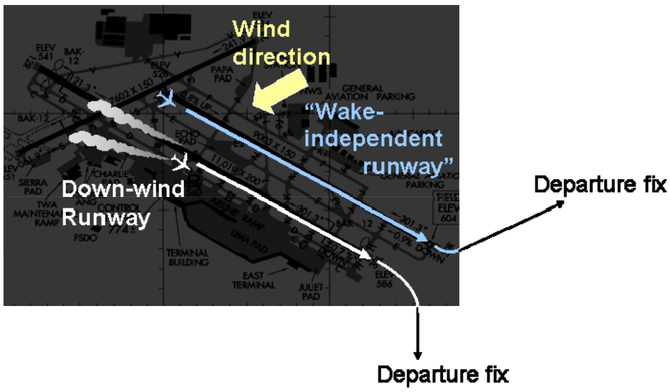


Fig. 1 WTMD Wind Condition

This means that departures on the upwind runway are not affected by wakes generated on the downwind runway, therefore wake separation of upwind runway departure traffic from traffic on the downwind runway is not required. Wake standards would still have to be applied between consecutive departures from the same runway and for departures from the downwind runway following departures from the upwind runway.

This concept has been refined and evaluated in two Human-In-The-Loop (HITL) simulations conducted at MITRE's Center for Advanced Aviation System Development (CAASD) simulation facility using the Lambert-St. Louis International Airport (STL) as the operational environment. The objectives of the first simulation were to determine requirements for full-up evaluations of CSPR departure procedures and to evaluate simulation characteristics and fidelity. The results indicated that the simulation was deemed satisfactory, and that the procedure appeared to be operationally feasible [4]. The second HITL simulation focused on the WTMD procedure usability, workload, and information requirements for the local controllers and supervisor, and display information requirements. Controllers found that using the WTMD procedures was relatively easy, with workload remaining within acceptable limits. Further, the prototype interface provided adequate information to accomplish responsibilities with respect to the procedure. Finally, departure rate improvements were observed when WTMD operations were in effect [5].

The next logical step in the evaluation of the WTMD procedure was a set of field deployments to candidate airports to determine the engineering feasibility of the WTMD system. In conjunction with the engineering feasibility studies, a supervisory assessment was conducted to determine the information requirements of airport traffic control tower supervisors and to validate the controller assessment simulation results.

2 Objective and Approach

The objective of the information requirements assessment documented here was to understand the supervisory controller decision-making process, information requirements, and information sources for authorizing, conducting, and terminating the WTMD procedure. During the data collection sessions, it became clear that comments received from subjects would not be limited to those which addressed the study objectives. These additional comments are also documented in this report. To meet the research objectives, data were collected from supervisor and controller-in-charge[1] personnel at both the Lambert-St. Louis International Airport (STL) and George Bush Intercontinental/Houston Airport (IAH) Airport Traffic Control Tower (ATCT) facilities. (Note that when the term "supervisor" is used in this document, it includes the controller-in-charge function.) The primary data collection mechanism was a

[1] "Controller-in-charge" is a designation for a controller who assumes overall responsibility for air traffic operations when a supervisor is not present in the tower.

questionnaire. Data collection sessions were conducted at the respective facilities, in administrative spaces. Specific details of the data collection sessions are provided in Section 5. Due to space limitations of this paper, an exhaustive reporting of the subject research effort is not possible. The full reporting of the results can be found in the following document: NASA/TM-2008-215114 [6].

3 WTMD Overview

The WTMD concept improves the efficiency of CSPR[2] operations by allowing upwind runway departures to be released independently of Heavy/B-757 aircraft operating on the downwind runway. Current wake separation standards do not account for crosswind transport of wakes and therefore require additional spacing beyond standard separation requirements. As an improved operational procedure, WTMD would be authorized only when wind conditions exist that prevent the transport of wakes from a downwind runway to an adjacent parallel runway. Specifically, when the crosswind component is three knots[3] or greater away from the trailing departure on a parallel runway, the procedure can be used. Departures may then be released from the "wake independent runway" without regard to wake turbulence generated from Heavy/B-757 aircraft departing on the downwind runway. This condition is verified through a wind forecast algorithm that incorporates current airfield wind and Rapid Update Cycle (RUC) forecast winds from the surface through 1000' above ground level (AGL). This resulting wind forecast volume contains the parallel runway departure paths up to the altitude at which diverging headings are initiated. If the wind forecast algorithm indicates the WTMD system is available, the ATCT supervisor may enable the system. The WTMD procedure is then put into effect, and the upwind runway becomes wake-independent. When the wind condition changes to a non-favorable cross-wind, the WTMD procedure must be terminated and dependent CSPR separation standards are then applied.

The ATCT supervisor is responsible for the activation, monitoring and termination of the WTMD procedure, while the ATCT local controller is responsible for implementing separation standards for the departure runways. Certain facilities may use two or more controllers to manage these runways, depending on their operation, e.g., dual use with arrivals or as dedicated departure runways.

Simplicity was the guiding principal in the development of the WTMD concept, so a simple "On or Off" procedure was developed in concert with a prototype WTMD status indication and alerting system/display.

To ensure that the WTMD procedure can be conducted safely, two features have been incorporated into the wind forecast algorithm: 1) the wind predictions that enable use of this procedure will be valid for at least 20 minutes, and 2) the prediction incorporates a three-minute guarantee; simply, at any given time, the winds will support use of the WTMD procedure for a minimum of three minutes. This permits the safe execution of any clearances issued should the WTMD system change status from "WTMD On" to "WTMD Off." Tools, in the form of prototype displays supporting the WTMD procedure were developed for the local controller assessment and more recently, in support of field implementations of the WTMD system and the supervisor assessment. These displays were, by design, simple, intending to convey the necessary information required to support the WTMD procedure. Note the sample of one such display in Fig. 2. In this case the supervisor has enabled one of the runways, the runway status indicator shows "WTMD ON" for that runway and other runway options are either "OFF" or "Available". One possible implementation of a WTMD display that could be implemented for the tower controllers is described in Reference 5. However, no decision has been reached on the particular implementation of operational

[2] CSPRs are defined as those with less than 2500' between runway centerlines.

[3] Below three knots, airfield wind measurements are unreliable in both magnitude and direction.

displays, and additional research is required.

Fig. 2. WTMD System Status Display

The final implementation will depend on local automation architectures, which vary from airport to airport.

4 Data Collection Locations

Two air traffic facilities were used for the information requirements data collection: STL and IAH. These facilities were selected based on the implementation of WTMD systems at these locations. The prototype WTMD system architecture was used for demonstration of the engineering feasibility of the WTMD system and for identifying system requirements. Both of these facilities have CSPRs which are used for departures.

5 Data Collection and Study Subjects

5.1 General Overview of Activity

The focus of the data collection activity with respect to the roles and decision-making process in implementing the WTMD procedure was on the supervisor position in the ATCT. The role of the supervisor with respect to the WTMD procedure is relatively simple: approve the use of, monitor as required, or terminate use of, the WTMD procedure. The process by which these decisions are reached may not be as simple and could vary significantly between individuals and between airports. Additional related decisions required of the supervisor included selection of, and changes to, runway configurations and arrival and departure procedures based on traffic demand and weather. With this in mind, the goal of the data collection effort was to understand how the supervisor arrives at a decision with respect to WTMD operations, what information is required, and the sources of that information.

5.2 Study Subjects

Study subjects were supervisory air traffic controllers and controllers that were controller-in-charge qualified. Facility management was briefed on the WTMD concept, study objectives and process, and coordinated participation for all subjects. Seventeen subjects participated in the data collection activity - 5 from STL and 12 from IAH. The backgrounds of the seventeen subjects represented extensive and broad-based experience in the ATC arena (see Section 6.1).

5.3 Training and Test Procedure

The WTMD concept is, by design, relatively simple. It follows that the tools and procedures are simple and straightforward so the time required for training is minimal. Training was accomplished through presentation of power point slides and hard copy briefing materials. This activity was conducted in one-on-one sessions.

The following test procedure was used. Data collection sessions began with a briefing focusing on the WTMD procedure, the role of the supervisor and local controller with respect to the procedure, and the WTMD display. The briefing was interactive and subjects were encouraged to ask questions as required to ensure an understanding of the concept. After the briefing, the applicability of the procedure to the subject's particular operation (i.e. STL or IAH) was discussed. It was readily apparent, based on these discussions, that all subjects sufficiently understood the concept from the briefing. Subjects were provided with a demonstration of the shadow-mode WTMD system followed by a discussion of the WTMD display. Subjects were then presented with three scenarios representing different operational conditions. The purpose of the scenarios was to provide a context for use of the WTMD procedure. The primary variables in the scenarios were weather conditions and traffic loading (current and projected). The scenarios all assumed that factors such as ATCT staffing and supervisor workload were within acceptable bounds to consider authorization of the procedure. Based on the scenarios, subjects were asked to respond with comments regarding the methodology in determining whether they would approve WTMD operations and to discuss the factors involved in reaching their decisions. Note that the emphasis was in determining the decision making process (including information requirements and sources), not whether or not they would have authorized the procedure under the conditions presented. However, some factors (such as flow restrictions at departure fixes) were introduced in the scenarios to determine if this might affect the decision to authorize the procedure. The final part of data collection was the administration of a questionnaire and subsequent concluding interview.

5.4 Data Collection

5.4.1. Data collected

Feedback was obtained through use of a structured interview guide and a questionnaire. Following the presentation of each scenario, the subjects would comment on what information was important and how they would go about making a decision to authorize the procedure. A structured interview guide was used to ensure basic subject areas were addressed. Following a demonstration of the shadow-mode system, comments were gathered concerning the status and alerting information. As the final activity in the data collection session, the subjects completed the questionnaire. After the questionnaire was completed, the researcher reviewed it with the subject to determine if any responses required clarification. The data collection session lasted from one and one-half to two hours depending on the extent of the discussion.

5.4.2. Interview guide and questionnaire

The interview guide was used during the course of the data collection session and the questionnaire was completed at the conclusion of the session. The intent of the interview guide was to foster a discussion of the concept and its use. This discussion was used to ensure that subjects understood the WTMD concept, gather general perceptions regarding the concept, and how it would be used at their facility. The questionnaire was divided into three sections: “General,” “Enabling and authorizing the WTMD procedure,” and “Disabling and terminating the WTMD procedure.” The “General” section address questions focusing on potential training requirements, use of displays in the tower in current environment and anticipated for a WTMD environment, and requirements for a WTMD status display. The “Enabling and authorizing the WTMD procedure”, and “Disabling and terminating the WTMD procedure” questions addressed processes and information requirements for those activities.

5.4.3 Data collection environment

The location for the prototype system and data collection were administrative office spaces, separate from the ATCT control room.

6.0 Results

Results indicated that the following information was required to support the conduct of WTMD operations: current and forecast weather information, current and forecast traffic demand and traffic flow restrictions, and WTMD System status information and alerting. Amplification on these requirements as well as others is provided in the following three sections. The first section addresses the subjects’ ATC experience and the following two sections discuss questionnaire quantitative results and comments offered by the subjects, respectively.

6.1 Subject ATC Experience

The seventeen subjects represented an extensive and broad base of experience in air traffic operations. Air traffic qualifications across the subjects included certifications for ATCT, Terminal Radar Approach Control (TRACONs), and Air Route Traffic Control Centers (ARTCCs). Additional experience included staff members from both the Operations as well as Support Specialists. Determining the level of ATCT experience for the IAH subjects was complicated by the fact that it was a "combined facility" until 1993. This meant controllers worked both the ATCT as well as the TRACON. Supervisors continued to work both facilities until 2004, at which time the supervisory functions at these facilities were also divided. Personal preferences also played a part in the experience they had accumulated in the ATCT or TRACON. To account for the uncertainties introduced by these conditions, a conservative estimate of ATCT experience was used. The average number of years ATC experience across the 17 subjects by facility type was as follows:

Average total years of ATC experience: 26.35
Average years ATCT experience: 16.23
Average years TRACON experience: 9.11

6.2 Questionnaire Quantitative Results

The questionnaire nominal data were analyzed using X^2 (Chi-squared) tests with significance set at $p \leq 0.05$. The calculated confidence interval for the 95% confidence level and the 17 subjects is 23.8%. There were no significant differences in responses between subjects from STL and IAH. Consequently, data from the two facilities were combined for the subsequent analyses.

Among the 17 subjects, 12 strongly agreed and five agreed that the training provided on the WTMD procedure was adequate. Therefore, the following results are predicated on the subjects understanding both the WTMD procedure and its related displays.

Subjects reported that obtaining information about whether to enable and authorize the WTMD procedure or to disable and terminate the WTMD procedure would be easy (Fig. 3). They also felt confident that they would be able to enable/authorize or disable/terminate the WTMD procedure with the information given.

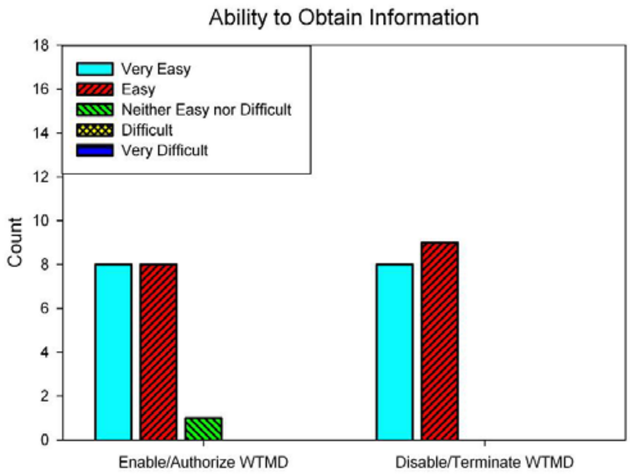
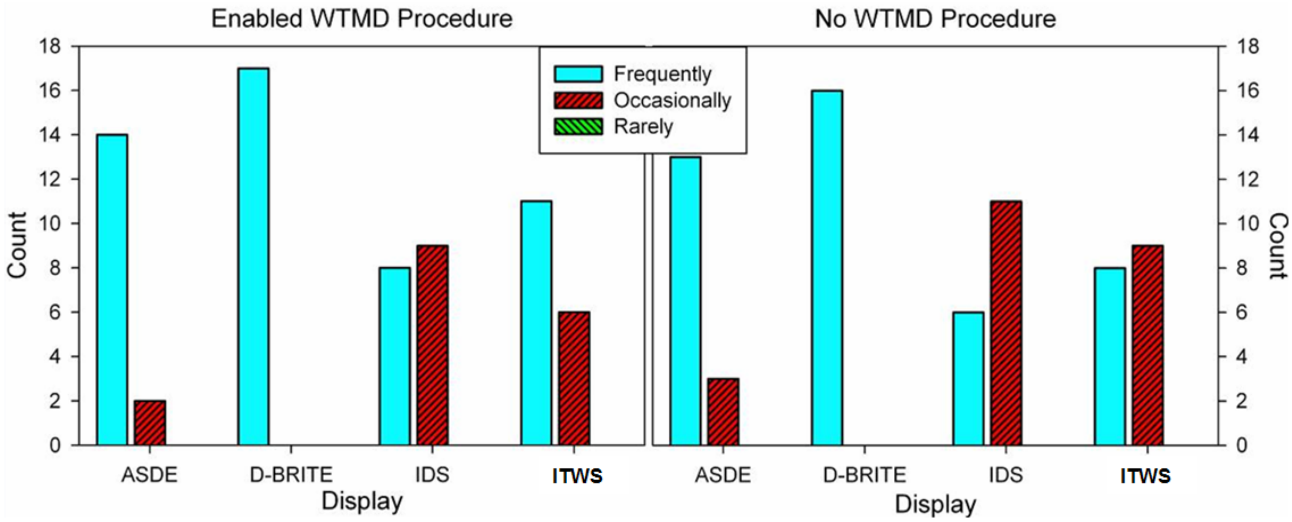


Fig. 3. Ability to Obtain Information Related to the WTMD Procedure

Of the 17 subjects surveyed, seven strongly agreed and 10 agreed that the information needed to determine the status of the WTMD procedure was sufficient. Even though the subjects deemed that the provided information relating to the WTMD procedure was sufficient, they also indicated that they would like to have the history of the status of the WTMD procedure. Thirteen of the17 subjects surveyed said this history would affect their willingness to enable and authorize the WTMD procedure. Thirteen of the 17 subjects also would like to know why the WTMD procedure became unavailable.

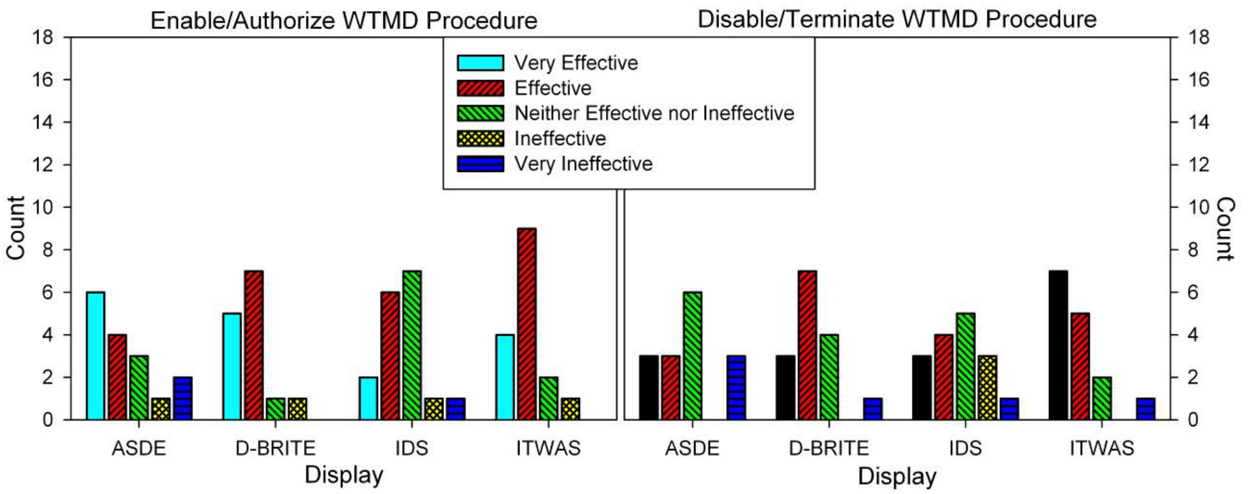
Regarding information commonly accessed, the subjects reported that they frequently look at the D-BRITE and ASDE displays for information (Fig. 4). With an Enabled WTMD procedure, supervisors stated they would not significantly change the displays they look at when compared to No WTMD procedure.



(a) (b)

Fig. 4. Displays Supervisors Normally Look At (a) Most Likely with an Enable WTMD Procedure and (b) with No WTMD Procedure

Subjects indicated that the displays they normally look at would also be helpful, in addition to the WTMD system state display, in enabling/authorizing or disabling/terminating the WTMD procedure (Fig.5). Supervisors judged that the Integrated Terminal Weather System (ITWS) display was the most effective for deciding to enable/authorize and disable/terminate the WTMD procedure. Supervisors did feel they would have to monitor the status of the WTMD procedure and its availability at least occasionally, whether or not it was active (authorized) (Fig. 6).



(a) (b)

Fig. 5. Display Perceived Effectiveness in Deciding to (a) Enable/Authorize or (b) Disable/Terminate WTMD Procedure

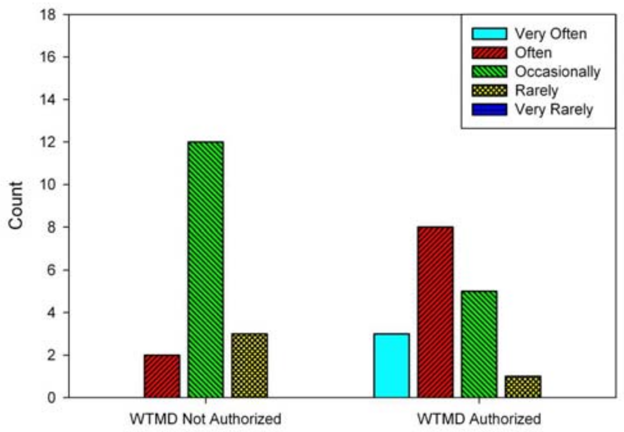


Fig. 6. Supervisors' Anticipated Requirements for Monitoring WTMD Information With and Without WTMD Authorized

A summary of the questionnaire results follows. The nominal questionnaire responses from IAH and STL, each with different parallel runway operations, did not vary significantly. Therefore, it is possible that the results from these two facilities may generalize to other facilities with parallel runway operations.

Overall, the results indicated that supervisors judged that the WTMD procedure and the information provided to them about its status were adequate. Supervisors felt that they would not have to modify their personal behaviors significantly, except for adding the monitoring of the WTMD-procedure status and possibly increasing the frequency of looking at the ITWS display.

Supervisors did indicate a desire to know the history of the WTMD-procedure status and why the WTMD procedure is no longer authorized (when that is the case). They stated that knowledge of the status history would affect their willingness to enable/authorize the WTMD procedure. Not surprisingly, supervisors felt they should have primary control of WTMD-related alarms.

Supervisors felt the WTMD procedure would benefit departure operations, even during low departure demand.

The survey results of ATC supervisors indicated that the WTMD procedure and its related displays are sufficient for supervisors to enable/authorize and disable/terminate the WTMD procedure.

The WTMD procedure may benefit all parallel runway operations by decreasing overall delays at the airport at which it is in use. But before this procedure is implemented, further human-in-the-loop testing is needed to confirm these supervisors' opinions.

6.3 General Comments

All subjects felt that the procedure was simple, easy to understand and would require minimal training to apply at their respective facilities. (This finding was underscored by the minimal exposure to the concept required for this research, after which subjects were able to provide useful and insightful comments.) Subjects universally reported that there was clear value for the WTMD procedure. There was general agreement that use of the WTMD procedure would require several actions including coordination with air traffic personnel in the ATCT, and coordination with other appropriate air traffic and airline organizations (e.g. TRACON, Center, Air Traffic Control System Command Center (ATCSCC), and Airline Operations Centers). The subject of "alerting" generated many comments from the subjects based on the number of alerts that already are implemented in the tower. (One subject identified six different alarms that currently exist in the tower.) Supervisors mentioned that appropriate alerting and alarm functionality that minimizes nuisance or false alarms is required. There was consistency among the subjects regarding the type of information that was accessed for day-to-day operations (weather, traffic loading, flow restrictions, etc.), the priority of accessing that information, and information that would be accessed during use of the procedure. Results indicate that WTMD training could be conducted in a reasonably short session that would include classroom training of the concept and WTMD systems and local procedure. Concerning the WTMD interface, results indicate that the WTMD status information needs to be hosted on an "appropriate" display in the tower cab, and supervisors indicated this should be situated near the wind and altimeter status displays. WTMD status information is safety critical, so it would need to have system reliability, integrity, and availability for a flight critical display. It was also generally felt that a repeater display of the WTMD status in the TRACON would be useful.

7 Concluding Remarks

The WTMD procedure offers the potential to significantly improve airport efficiency. Central to the implementation of WTMD is acceptance by the ATCT supervisor or controller-in-charge, who would authorize its use. Part of this acceptance is ensuring that the necessary information is readily available by those authorizing the procedure. This data collection activity identifies that information. In the process of collecting that data, information in other areas relating to WTMD was captured and is included in the results.

Results indicated that the following information was required to support the conduct of WTMD operations: current and forecast weather information, current and forecast traffic demand and traffic flow restrictions, and WTMD System status information and alerting.

Two WTMD prototypes were developed that placed WTMD status information onto a display accessible to the supervisor – the STL prototype had WTMD information on the ACE-IDS, and the IAH prototype had WTMD information on the IDS-4. The general supervisor acceptability of these prototypes demonstrated that WTMD information can be displayed on platforms suitable to a candidate airport's ATCT equipment. Specific WTMD architecture and display designs should be considered by trade study.

Both quantitative questionnaire data and comments recorded from interviews were consistently favorable to the WTMD concept and supporting procedure. All subjects felt that the WTMD procedure offered operational benefits, even in low demand periods, and could be easily applied at their respective facilities. All subjects also felt that the information necessary to support the procedure was currently accessible in their respective facilities. They further felt that it would take minimal training time to understand WTMD and to feel comfortable with the process of authorizing, monitoring, and terminating the WTMD procedure. Supervisor subjects indicated that using the WTMD procedure would not significantly change their behavior, including the displays they would usually use in the course of performing normal duties. The manner in which "alerting" was provided for changes in the WTMD status was of concern among most subjects and requires further research. There was general agreement among the subjects that historical data concerning the WTMD status would be useful and would affect their willingness to authorize the procedure. Finally, there was consensus that authorization to use the WTMD procedure would require certain actions. Examples include updating the ATIS broadcast to indicate the use of WTMD Operations, coordinating with other ATCT and adjacent facilities, making a log entry, among possibly others

Acknowledgements

The authors gratefully acknowledge Edward Johnson and David Domino for their contributions to this paper.

The research team also gratefully acknowledges the cooperation and assistance of the following organizations in support of this data collection effort.

The FAA Wake Vortex Program Office

The Lambert-St. Louis International Airport Traffic Control Tower

The George Bush

Intercontinental/Houston Airport Traffic Control Tower and TRACON

The MITRE Corporation

References

[1] FAA, February 2006, *Air Traffic Control*, FAA Order 7110.65S, Federal Aviation Administration, Washington, D.C.

[2] Lang, Steve, J. Tittsworth, C. Lunsford, W. Cooper, L. Audenaerd, R. Cole, *An analysis of potential capacity enhancements through wind dependent wake turbulence procedures.* Federal Aviation Administration, Washington D.C. May 2005

[3] Lunsford, C. R., P. Moertl, J. Tittsworth. *Initial concept of use for Closely Spaced Parallel Runways (CSPR) wind-dependent departures,* MP 05W0000285,. The MITRE Corporation, McLean, Virginia., November 2005

[4] Mundra, Anand, C. Lunsford, A. Oswald, L. Ross., Presentation: *Preliminary results from the simulations for proposed CSPR wind dependent departure procedure,* The MITRE Corporation, McLean, Virginia, March 2005

[5] Domino, David A., C. Lunsford, P. Moertl, A. Oswald. *Controller assessment of procedures for wake turbulence mitigation for departures (WTMD) from closely spaced parallel runways,* MP 06W0000102, The MITRE Corporation, McLean, Virginia, May 2006

[6] Lohr, Gary W., D. Williams, A. Trujillo, E. Johnson, D. Domino. *Information Requirements for Supervisory Air Traffic Controllers in support of a Mid-Term Wake Vortex Departure System.* NASA/TM-2008-215114, February 2008

[7] Lang, Steve, J. Tittsworth, C. Lunsford, W. Cooper, L. Audenaerd, R. Cole, *An analysis of potential capacity enhancements through wind dependent wake turbulence procedures.* Federal Aviation Administration, Washington D.C. May 2005

Copyright Statement