Dallas/Fort Worth International Airport Perimeter Taxiway Demonstration

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16. Abstract

Currently, the Dallas/Fort Worth International Airport (DFW) experiences about 1,700 runway crossings per day, which contribute to arrival and departure delays and the potential for runway incursions. In an effort to enhance DFW operations, a perimeter taxiway (PT) concept was proposed that included new PTs on the East and West sides of the airport. DFW, the Federal Aviation Administration, and the National Aeronautics and Space Administration (NASA) conducted a real-time human-in-the-loop simulation that demonstrated the effect of adding new PTs to DFW. The demonstration was conducted in February 2003 at the NASA Ames Research Center (ARC). The primary objective was to provide the airlines, air traffic controllers, pilots, and their associated unions the opportunity to observe and participate in a demonstration of the proposed airport improvements at high fidelity levels with the goal of gaining their acceptance of PTs. The secondary objective was to collect and analyze operational data to derive descriptive statistics. NASA ARC facilities were used to simulate DFW tower and flight deck operations. The simulators were integrated and ran simultaneously for all runs during 4 days of demonstration. Five Certified Professional Controllers from DFW and seven representatives from the airlines participated. Two taxiway configurations were simulated to represent the current DFW configuration and the proposed configuration with the new PTs. All controller and pilot participants agreed the demonstration was a good representation of operations at DFW and the proposed new taxiways. Overall, the data collected from the participants and the simulators demonstrated that the PTs would improve operations at DFW, if implemented. Improvements were observed in many areas including average departure rates, average outbound taxi duration and associated runway occupancy times, average inbound and outbound stop rates and duration times, the number of runway crossings, and the amount of controller and pilot communications.

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Executive Summary

Currently, the Dallas/Fort Worth International Airport (DFW) typically experiences about 1,700 runway crossings per day, which contribute to arrival and departure delays and the potential for runway incursions. In an effort to enhance DFW operations, a perimeter taxiway (PT) concept was proposed that would include new PTs on the East and West sides of the airport. Many fast-time simulations and paper studies have been conducted that support the cost benefit, efficiency, and safety aspects of the proposed airport improvements. However, prior to the Dallas/Fort Worth International Airport Perimeter Taxiway (DAPT) Demonstration, the improvements had not been observed or assessed in an operational setting using high fidelity simulation with human operators. Therefore, a partnership effort involving DFW, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA) was formed to conduct a real-time human-in-the-loop simulation that demonstrated the effect of adding new PTs to DFW. The DAPT Demonstration was conducted in February 2003, at the NASA Ames Research Center (ARC) in Moffett Field, California. The FAA William J. Hughes Technical Center acted as Principal Investigator and provided support for the research team.

The primary objective of this endeavor was to provide the airlines, air traffic controllers, pilots, and their associated unions (i.e., the National Air Traffic Controllers Association, Airline Pilots Associations, and Allied Pilots Association) the opportunity to observe and participate in a demonstration of the proposed airport improvements at high fidelity levels with the goal of gaining their acceptance of PTs. In particular, there were four "views" of special interest for the demonstration 1) the controller view, 2) the pilot-on-taxi view, 3) the pilot-on-arrival view, and 4) the pilot-on-departure view. The secondary objective was to collect and analyze operational data for the purpose of deriving descriptive statistics for runway crossings, taxi times, and pilot and controller transmissions.

NASA ARC's FutureFlight Central (FFC) Facility and Crew Vehicle Systems Research Facility (CVSRF) were used to simulate DFW tower operations and flight deck operations respectively, at high fidelity levels. FFC and CVSRF were integrated and ran simultaneously for all runs. There were 4 days of demonstrations (including training). East-side, South flow, day time traffic operations at DFW were simulated. Traffic scenarios were created using DFW operations data modified as needed to create future demand levels and the desired traffic mix.

Five Certified Professional Controllers from DFW staffed the FFC simulator. Two taxiway configurations were simulated during 13 runs. The Baseline (BL) condition represented current DFW configuration, whereas the PT condition included the proposed new PTs, the extension of Runways 17C, and a new high speed exit on 17C (exiting to the East).

One staff pilot and seven representatives from the airlines flew the Boeing 747-400 flight simulator. The participating pilots engaged in at least 1 of the 4 days of the demonstration. Pilots were encouraged to experience all "views" defined in the objective of the demonstration, in addition to certain predefined typical views.

Controller and pilot subjective ratings, objective data captured from the simulators, and communications data were obtained throughout the demonstration. The objective data captured included taxi time durations, various arrival and departure data, runway occupancy times, inbound and outbound taxi statistics, runway crossing data, and pilot and controller communications data.

In general, the subjective and objective data demonstrated that the PTs would improve operations at DFW, if implemented. The results revealed many interesting distinctions between the BL and PT conditions. However, because this was a demonstration, it is imperative to recognize that all results should be used and interpreted with caution.

All controller and pilot participants agreed the demonstration was a good representation of operations at DFW and the proposed new taxiways, and all perceived a marked improvement from BL to PT conditions. The participating controllers believed that the implementation of PTs in the demonstration enabled an overall more efficient operation. They felt the PTs provided for a smoother flow of traffic, afforded better ability to move aircraft to and from the runways, improved situation awareness, and decreased workload demands. Pilot participants thought the PTs improved efficiency and increased safety by reducing the potential for runway incursions. They also speculated that PTs would improve airline performance rates and reduce both pilot and controller workload due to less frequency congestion and a reduction in hold-short instructions.

The objective data resulting from the demonstration supported the participants' verbal comments. Both indicated that the PTs would improve operations at DFW if implemented. Arrival rates for the BL and PT conditions remained consistent (by design), but there was a substantial increase in the departure rate per hour for the PT condition. The average inbound taxi duration increased in the PT condition. However, the average outbound taxi duration and associated runway occupancy times showed improvements with PTs compared to BL runs, as did inbound and outbound stop rates and duration times. Furthermore, by design, PTs completely eliminated runway crossings at DFW in the demonstration.

Controller and pilot communications for the most critical frequency were clearly reduced with the addition of PTs. On the Local East 1 (LE1) frequency, significantly fewer transmissions were made (22% relative reduction) with fewer words spoken (27% relative reduction). This resulted in the controllers and pilots spending less time on frequency (24% relative reduction) when compared to BL runs. Words were also spoken slightly slower on average during PT runs. In addition to being operationally relevant, these results were also statistically significant for the LE1 frequency. Such findings were consistent with controller debrief comments; controllers felt that the volume of communications was significantly reduced and that they used less verbiage because concerns about crossings and reliance on pilot readbacks were alleviated. Many of the positive data results were also apparent in the findings of the other frequencies, but generally to a lesser degree.

Based on the results of the data collected from the demonstration, it was clear that all objectives of the exercise were met successfully. The controllers and pilots were afforded the opportunity to observe and experience the proposed airport improvements with realism and high fidelity, and a considerable amount of valuable data was available for analysis and is presented in this report.

1. Introduction

This report describes the results of a real-time human-in-the-loop (HITL) simulation that demonstrated the effect of adding new perimeter taxiways to the Dallas/Fort Worth International Airport (DFW). The Dallas/Fort Worth International Airport Perimeter Taxiway (DAPT) Demonstration was a partnership effort involving DFW, the Federal Aviation Administration (FAA), and the National Aeronautics and Space Administration (NASA). The DAPT Demonstration was conducted February 10-13, 2003, at the NASA Ames Research Center (ARC) in Moffett Field, California. The data presented in this report are results from controller and pilot subjective ratings, objective data captured from the simulators, and communications data.

This research endeavor was primarily designed to be a demonstration and was not focused on providing data with high fidelity or statistical rigor (i.e., there is limited power for the use of statistical data analysis). The data provide a snapshot of the impact of the proposed DFW perimeter taxiway (PT) operation with human operators (i.e., controllers and pilots) included. It is acknowledged that the data sample is small, participants were limited, and the runs were of variable length. Due to the variable run lengths, objective data were often converted to hourly rates. Inferential statistics were used as appropriate. For most of the data, however, inspection of descriptive statistics (e.g., frequencies, medians, and means) was used as the primary method for evaluation.

Because this was a demonstration, it is imperative that all results presented are to be used and interpreted with great caution. Results should not be generalized or accepted as conclusive.

In addition to this report, an informational video of the demonstration and proposed airport improvements was developed and will be shared with the National Air Traffic Controllers Association (NATCA), International Civil Aviation Organization (ICAO), National Academy of Sciences, International Council of Airports, Airline Pilots Associations (ALPA), the Allied Pilots Association (APA), and others. The video can be obtained by contacting DFW (perimetertaxiways@dfwairport.com).

1.1 Background

Currently DFW typically experiences approximately 1,700 runway crossings per day. The existing configuration at DFW requires that aircraft arriving on the East-side Runway 17C-35C cross the departure Runway 17R-35L, and aircraft arriving on 17L-35R cross both the arrival Runway 17C-35C and the departure Runway 17R-35L. The aircraft arriving on Runway 31R must also cross both Runways 35C and 35L. Similarly, the aircraft arriving on the West-side Runway 13R must cross both the arrival Runway 18R-36L and the departure Runway 18L-36R, and aircraft arriving on 18R-36L must cross the departure Runway 18L-36R. Figure 1 depicts the DFW runways, terminals, three control towers, and existing taxiways and bridges.

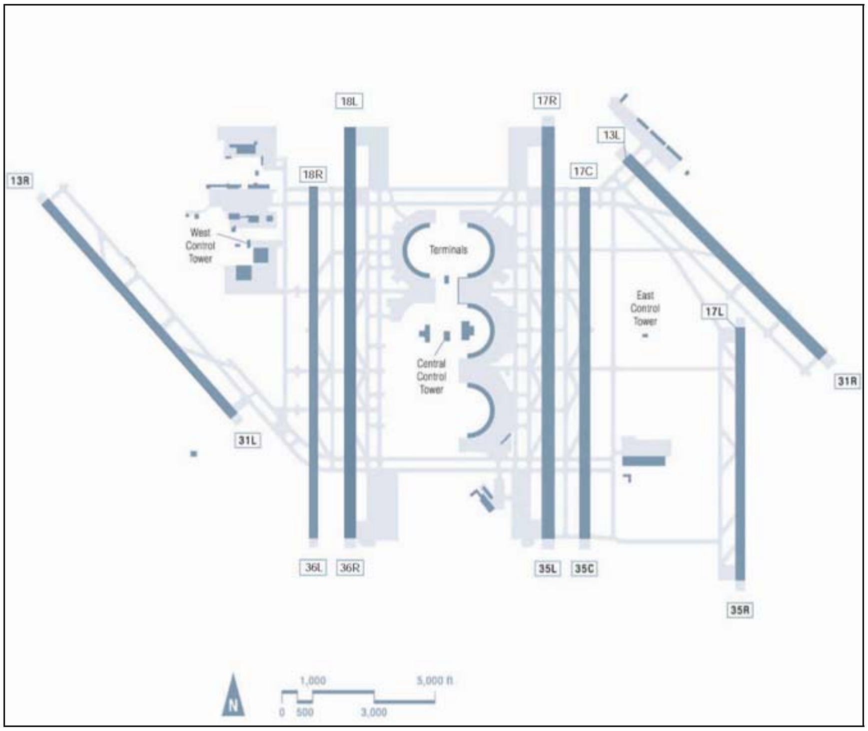

Figure 1. DFW current configuration.

Under current operations, the local controller must conduct all runway crossings before the aircraft can be released to the ground controller. This situation increases the local controller's workload in meeting airport demand mainly due to frequency congestion and challenges the local controller to fully utilize the available runways. During major arrival and/or departure pushes, tradeoffs are sometimes made to safely balance all operations. When the local controller maintains the airport departure demand, runway crossings for arriving aircraft can be delayed due to having to cross the departure runway. Similarly, when arrivals stack up at the various runway-crossing points forcing the local controller to meet this demand, departures are 'gapped' to accommodate these crossings. These situations are most evident during the peak traffic times.

In an effort to reduce arrival and departure delays and the number of active runway crossings (with the added benefit of reducing runway incursion potential), a PT concept is proposed. The concept includes new PTs on the East and West sides of the airport, and two new high speed exits each on 17C and 18R. Figure 2 shows an aerial perspective of the proposed new PT concept.

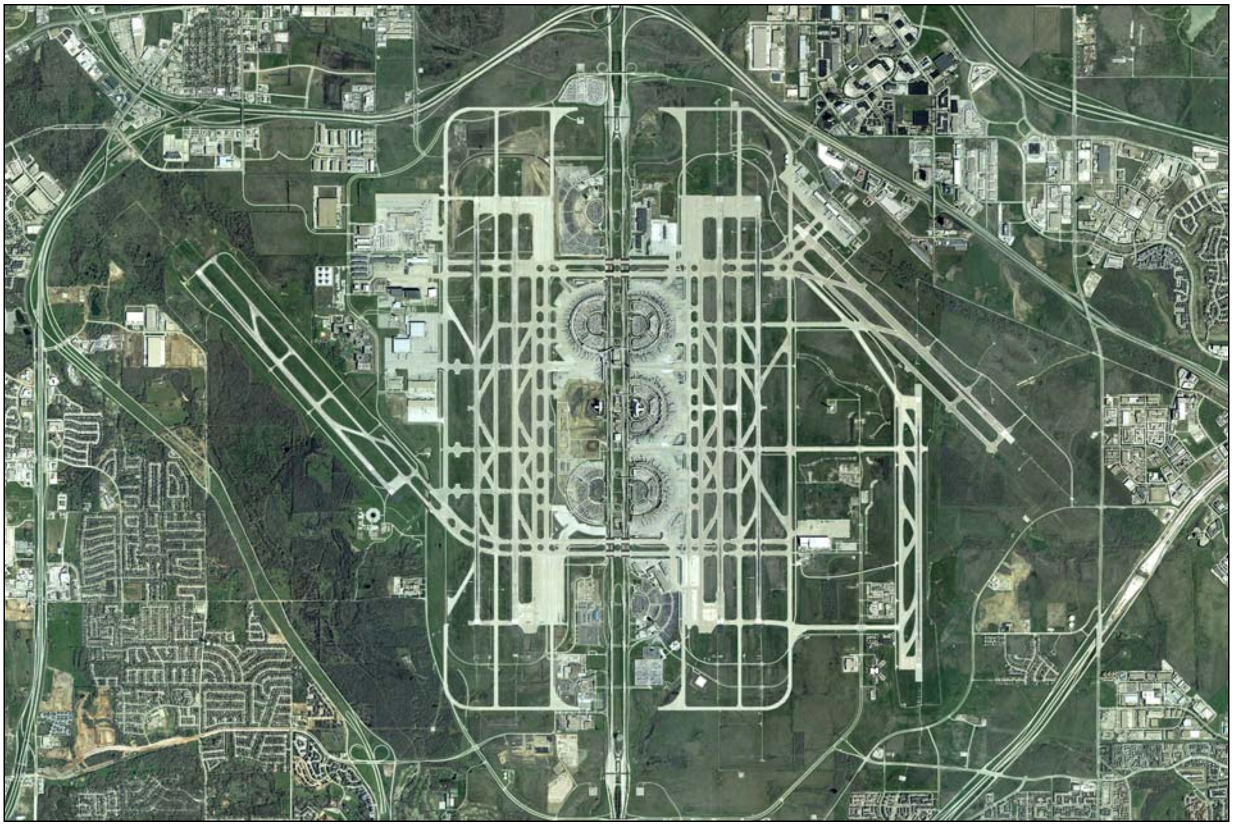

Figure 2. DFW with proposed PTs.

Many fast-time simulations and paper studies have been conducted over the last 7 years that support the cost benefit, efficiency, and safety aspects of the proposed airport improvements. It has also been determined that no waivers will be needed for the new taxiways. However, prior to the DAPT Demonstration, the improvements had not been observed or assessed in an operational setting using high fidelity simulation with human operators. In particular, there were four "views" of special interest for the demonstration: 1) the controller view, 2) the pilot-on-taxi view, 3) the pilot-on-arrival view, and 4) the pilot-on-departure view.

An Experiment Working Group (EWG) was formed to plan, conduct, and analyze the DAPT Demonstration to examine the proposed new PTs. Organizations represented on the EWG were DFW, DFW Tower/TRACON, FAA Southwest Region Charter Program Office (ASW-1C1), FAA Office of System Capacity (ASC-100), NASA ARC, the FAA William J. Hughes Technical Center Simulation and Analysis Group (ACB-330), and NATCA. Other organizations involved in the effort included FAA Flight Standards Service (AFS), FAA Office of Runway Safety (ARI), ALPA, APA, and American Airlines, American Eagle Airlines, Atlantic Southeast Airlines, Comair, Delta Airlines, and United Parcel Service Airlines. DFW and the FAA sponsored the study.

1.2 Objectives

The primary objective of this real-time HITL demonstration was to provide the airlines, air traffic controllers, pilots, and their associated unions (i.e., NATCA, ALPA, APA) the opportunity to observe and participate in a demonstration of the proposed airport improvements at high fidelity levels with the goal of gaining their acceptance of PTs. The secondary objective was to collect and analyze operational data for the purpose of deriving descriptive statistics for runway crossings, taxi times, and pilot and controller transmissions.

2. Method

The demonstration was conducted at NASA ARC in Moffett Field, California. FAA ACB-330 acted as Principal Investigator and provided support for the research team. NASA ARC's FutureFlight Central (FFC) facility and Crew Vehicle Systems Research Facility (CVSRF) were used to simulate DFW tower operations and flight deck operations respectively, at high fidelity levels. FFC and CVSRF were integrated and ran simultaneously for all runs. Table 1 highlights key aspects of the demonstration design.

Table 1. Summary of the Demonstration Design

Summary of the Demonstration Design
• Five Certified Professional Controllers from DFW staffed the FFC simulator
• One staff pilot and seven representatives from the airlines flew the Boeing 747-400 (B744) flight simulator
• 25 pseudo-pilots flew all other simulated aircraft targets
• There were 4 days of demonstrations (including training)
• East-side tower operations at DFW were simulated
• South flow traffic operations at DFW were simulated
• Two taxiway configurations were simulated – Baseline (BL) represented current DFW configuration and operations – PT included the proposed PTs, the extension of Runways 17C, and a new high speed exit on 17C (exiting to the East)
• For the PT conditions, 17C was lengthened on the approach end and a Precision Approach Path Indicator (PAPI) was installed for the newly lengthened runway for visual glideslope guidance
• Traffic scenarios were built to be approximately 45 minutes in duration
• Traffic scenarios were created using DFW operations data modified as needed to create future demand levels and the desired traffic mix – The arrival and departure rates for both BL and PT reflected future demand levels of DFW operations that exceeded current peak demand by approximately 20 to 30% – The fleet mix represented a realistic projection for the 2003-2006 time frame. Regional Jets, Boeing-757s, and heavy aircraft were increased, and the number of large jets (non- Regional Jets) and turboprops were decreased
• Aircraft taxi speeds were limited to the following for all runs: – "Fast" speed: 50 kts (limited to extended taxiing on runways) – "Normal" speed: 20 kts (for standard taxi operations) – "Slow" speed: 10 kts (cornering, ramp operations, congested traffic, etc.) • These speeds were applied to all aircraft in the simulation, regardless of airline company or aircraft type
• All conditions represented daytime visual meteorological conditions reflecting VFR conditions with a ceiling of 5000 ft and 5 miles visibility
• During BL conditions, the tower was staffed with five positions: Ground East 1 (GE1), Ground East 2 (GE2), Local East 1 (LE1), Local East 2 (LE2), and Cab Coordinator East 1(CCE1)
• During PT conditions, the tower was staffed with five positions: GE1, GE2, Ground East 3 (GE3), LE1, and LE2

For further details and information about the demonstration including methods used, experimental design, laboratory platforms, participants, scenarios, procedures, schedules, and so on, please see the DAPT Demonstration Experiment Plan Version 8 (dated 9/6/2002). The document can be obtained by contacting the FAA (karen.buondonno@faa.gov). The following paragraphs describe the only notable deviations from the experiment plan.

Originally, the demonstration intended to complete a total of 12 data collection runs during which pilots of the B744 flight simulator would fully interact with controllers in the tower simulator. The B744 simulator was to be fully linked to the FFC tower and simulated flights were to be incorporated to interact with the tower for nine of the runs. Each day, pilots were intended to fly the B744 simulator in two data collection runs for a total of six pre-defined flight segments. During each flight segment, the flight crew was to experience one of the following desired "views": an arriving flight passing over taxiing traffic on the Northeast perimeter; a departing aircraft passing over taxiing traffic on the Southeast perimeter; an aircraft taxiing on the Northeast perimeter with arrivals passing over it; or, an aircraft taxiing on the Southeast perimeter with departing traffic passing over it. Flight segments were intended to last approximately 5-15 minutes per run. The third and final run of each day for the pilots was to be an unstructured "Free Form" run that lasted for 45 minutes. During the Free Form run, the B744 flight simulator was not to be visible to the Air Traffic Control (ATC) side of the operation. The flight crew was to be given a menu of options from which they selected to experience a variety of additional conditions of interest. Menu items were to include such options as an arriving flight passing over taxiing traffic on the perimeters, a departing aircraft passing over taxiing traffic on the perimeters, an engine-out departure, IFR or VFR conditions, day or night environments, and eye point adjustments to simulate different aircraft types.

Due to technical difficulties, there were several changes. The original plan called for 2 of the 12 planned runs to be simulated as nighttime runs in FFC. The EWG decided to eliminate nighttime runs. In the end, there were 13 data collections runs instead of 12, and the runs were of variable length. As planned, the B744 simulator pilots participated in the demonstration at least 1 of the 4 days of the pilot demonstration. However, the original two-way link designed for the pilots to fully interact with the tower was degraded, and the link was adjusted to transmit data one-way. Therefore, pilots received information from the tower, but the B744 was not visible or audible to the controllers. The experiment design was adjusted to have the pilots run "Free Form" (as discussed previously) throughout the entire demonstration. They were encouraged to experience all "views" to be demonstrated from the original scenarios in addition to the "menu items." Pilots rotated throughout positions during and after each run. Preliminary procedures for PT operations were developed for use in the demonstration and presented in the experiment plan. Prior to the demonstration more detailed operational procedures for standard taxi routes were developed and briefed to the controllers. Therefore, the following procedures serve to replace those found in the DAPT Demonstration Experiment Plan Version 8.

Figure 3 and the following describe the new standard taxi routes for arrivals used by ATC during PT runs.

- ARRIVALS to 17L
  - Arrivals from 17L joined the Southeast Perimeter Taxiway from Taxiway P and turned North on Taxiway JS

- ARRIVALS to 17C
  - Non-heavy aircraft joined the Southeast Perimeter Taxiway from Taxiway M and turned North on Taxiway JS
  - Heavy aircraft joined the PT from Taxiway P (heavy aircraft were required to exit the runway to the East due to tail height) and turned North on Taxiway JS
- After joining Taxiway JS, aircraft were segregated based on their destination terminal
  - Aircraft parking at Terminals A and C – these aircraft transitioned from Taxiway JS to Taxiway L at Taxiway ER and held short of Taxiway EL
  - Aircraft parking at Terminals E & West side – these aircraft transitioned from Taxiway JS to Taxiway K and held short of Taxiway A
- All arrival aircraft on the Southeast Perimeter Taxiway changed frequencies to monitor GE2 turning North on Taxiway JS

Figure 3. PT arrivals standard taxi routes.

Figure 4 and the following describe the new standard taxi route for departures used by ATC during PT runs.

- DEPARTURES
  - Aircraft taxiing to Runway 13L for departure taxied North on Taxiway K, transitioned to Taxiway J via Taxiway Y, and joined the Northeast Perimeter Taxiway. These aircraft held short of Taxiway N and changed frequencies to contact LE2 after crossing Taxiway M

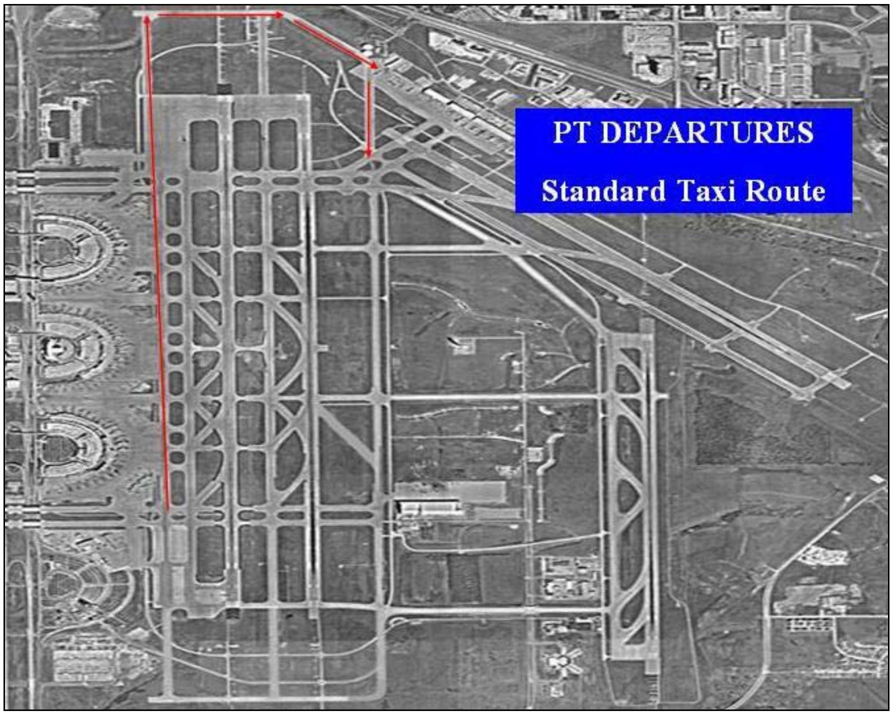

Figure 4. PT departures standard taxi route.

2.1 Limitations and Constraints

Simulation is a powerful tool for analyzing, designing, and operating complex systems. It enables hypotheses testing without having to compromise safety in the real world. It is a cost-efficient method to check the understanding of the surrounding world and can help produce better results faster for a research question. It can also be a very effective way to show how an operation works while stimulating creative thinking about how it can be improved. However, all simulation techniques make assumptions about the environments they are representing. It is very important to understand and realize the impact of such assumptions as they also often include limitations and constraints that must be considered when examining the results and conclusions.

The DAPT Demonstration employed a real-time method of simulation, that is, human participants (i.e., controllers and pilots) interacted with and reacted to the simulated aspects of the operational environment in real-time. Because it was purposely designed to be a demonstration (i.e., less data rigor and limited experimental design), it is particularly important to recognize and consider the implication of its limitations. The following is a list of the limitations and constraints experienced in the DAPT Demonstration (note: all participants were advised of the potential for these irregularities prior to the start of the exercise).

- The Digital Bright Radar Indicator Tower Equipment (D-BRITE) was available to controllers but was not as informational as the field version (e.g., no time share, no groundspeed, no heavy designator, departures do not tag until 2.5 nm South);
- The Airport Surface Detection Equipment (ASDE) -3 orientation was off by about 90 degrees (North-South orientation);

- The ATC communications system was a "touch screen" emulation of the field system. There was no intercab communications and there were no West-side coordination calls because only the East-side tower operations were simulated;
- There was a slight delay (0.5 second) inherent in the digital communications system,
- Pseudo-pilot software anomalies occasionally caused aircraft to appear to stop or jump while taxiing;
- Pseudo-pilots were responsible for "flying" multiple aircraft in the simulation. Their task load demand caused an increase in controller repetition of clearances and calls, and pilot voices for different aircraft were often the same;
- Visual cues occasionally appeared odd to the controllers. For example, objects appeared slightly farther or closer than normal and controllers occasionally had difficulty discerning aircraft type;
- Technical glitches in the software caused a few aircraft to "wheelbarrow" (i.e., nose-down landing) down the runway on arrival, or "spin" on their tail at the ramp. These aircraft were removed from the runs when encountered;
- The aircraft simulator is a high fidelity representation of a B744. Because there are so few Boeing 747 aircraft at DFW, the eye point of the aircraft was lowered to better represent the experience of a McDonnell Douglas 80 (MD-80);
- In the aircraft simulator, the visual software limited the out-the-window view to the 16 closest aircraft, occasionally causing surrounding aircraft to mysteriously appear or disappear;
- A Traffic Alert and Collision Avoidance System (TCAS) issue was identified in the simulator cockpit during the demonstration. Because pilots flew "free form" the whole demonstration (moving about freely, invisible to FFC controllers, hovering, parking on the end of the runway, etc.), unlikely traffic situations were showing up on the display and distracting the pilots. It was felt that TCAS was not crucial to the experience of the participating pilots, therefore, TCAS was turned off to reduce the distraction, and;
- There were technical issues with the simulation software that caused several runs to be terminated prematurely. Four of the 13 runs in the dataset terminated prior to the approximate 45-minute design time for the exercises. Based on pre-set criteria, two of those runs were too short (i.e., less than 30 minutes) to be included in the data analyses.

Though the list may seem long, in general, these limitations were normal for a demonstration of this complexity. For example, though it may seem to skew the results because there was increased controller repetition of clearances, it happened in both conditions (PT and BL), so the comparison of interest was not significantly affected. It is certainly important to identify such potential sources of bias, but in actuality, those listed previously only minimally affected the data and the experience of the participants. When asked, the participating controllers and pilots indicated these limitations and constraints only slightly affected their experience.

3. Results

There were 13 runs in the demonstration that included six BL runs and seven PT runs. Table 2 describes the condition and duration of each run. Run order was sequential as listed in the table. Though data for the 13 runs have been recorded, retained, and analyzed, two of the runs (Runs 1 and 9) did not meet the pre-set 30-minute minimum run length criterion to be included in the final data results. Shorter runs would not accurately capture the affect of surges, lulls, or build up in the traffic flow. For example, a short run would not experience the typical cumulative build up of delay, which could distort measurements such as taxi durations, runway crossings, stop durations, frequency congestion, and so on. Also, due to an isolated technical issue, communications data for one PT run (Run 2) were not captured. All other Run 2 data were included in the results.

Table 2. Summary of Runs

Run	**Condition**	**Duration (min:sec)**
1[a]	BL	22:38
2	PT	47:28
3	PT	44:07
4	BL	45:16
5	PT	35:48
6	BL	45:12
7	PT	32:46
8	PT	45:10
[illegible]	BL	16:36
10	PT	43:30
11	BL	45:21
12	BL	45:20
13	PT	47:41

[a]* Not included in results reported due to run lengths less than 30 minutes.

3.1 Subjective Data

Questionnaires were distributed to participating controllers and pilots to elicit opinions about their demonstration experience. Responses from controller and pilot participants are presented in both descriptive and graphical formats in the following sections. Debrief sessions and comments on questionnaires were summarized and included where appropriate, with particular emphasis on interesting or recurring themes.

All questionnaires, including ATC Post-Run, ATC Post-Demonstration, and End-of-Day Pilot Questionnaires were designed using 7-point Likert scales. Therefore, all rankings ranged from 1 to 7; however, the anchors varied according to the accompanying statement or question. In the following sections, anchors are provided both in the graphs and discussion of each specific question.

Data analysis for the questionnaires consisted of deriving descriptive statistics for each individual question. For the purpose of reporting responses, the overall median scores were used to describe the data. The median score is the most appropriate measure of central tendency when using ordinal data or when scores are not normally distributed. The median is the value above or below which one half of the observations fall. When there is an even number of observations, no unique center value exists, so the mean of the two middle observations is taken as the median value. The charts and tables in the following sections provide the frequency and median to further describe the distribution and allow for an assessment of the responses.

3.1.1 ATC Results

3.1.1.1 ATC Post-Run Questionnaires

Post-Run Questionnaires were administered to participating controllers after each run. Overall ratings for the Post-Run Questionnaires were positive and, in general, the controllers perceived a marked improvement from BL to PT conditions. Table 3 provides a summary of the questions and results. More detailed results and summaries for individual questions (or groups of questions) follow.

Table 3. ATC Post-Run Questionnaire Summary

	Question		n[1]	Median	Scale
1	Rate your ability to move aircraft "to and from the runways" during this run.	BL	19	5	1= extremely poor
		PT	33	7	7= extremely good
2	Rate your overall level of situation awareness[2] during this run.	BL	20	6	1= extremely poor
		PT	35	7	7= extremely good
3	Rate your situation awareness for current aircraft locations during this run.	BL	20	6	1= extremely poor
		PT	35	7	7= extremely good
4	Rate your situation awareness for projected aircraft locations during this run.	BL	20	6	1= extremely poor
		PT	35	6	7= extremely good
5	How much coordination was required with the other controllers during this run?	BL	20	1.5	1= very little
		PT	35	1	7= a great deal
6	Rate the difficulty of this run.	BL	20	6	1= extremely easy
		PT	35	4	7= extremely difficult
7	What was the level of traffic complexity under your control during this run?	BL	20	5.5	1= extremely low
		PT	35	5	7= extremely high
8	How would you rate the overall level of efficiency of this operation?	BL	20	5	1= extremely poor
		PT	35	7	7= extremely good
9	Rate the performance of the pseudo-pilots in terms of their responding to your control instructions, providing readbacks, etc.	BL	20	5	1= extremely poor
		PT	35	7	7= extremely good

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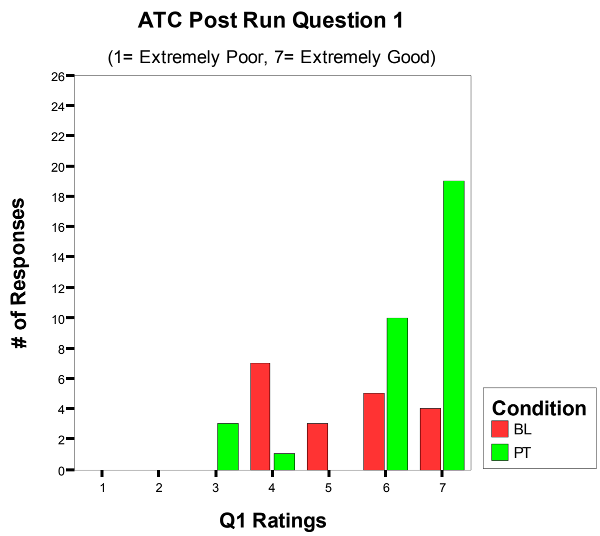
[1] n = number or observances (e.g., controllers who answered, pilots who answered, runs included)

[2] Because there are various interpretations of the term "situation awareness", for this demonstration, the participants were instructed that to have good situation awareness was to maintain awareness of the present state of events (at the lower end of the scale) and to be able to predict and anticipate future events (at a higher end of the scale) in the dynamic environment. In other words, a rating of 1 to 3 would indicate more of a reactionary control strategy perhaps due to traffic volume, frequency congestion, etc., whereas a higher rating of 5 to 7 would reflect an approach that was more proactive in nature.

Question 1

Controllers reported that they felt better able to move aircraft “to and from the runways” in the PT condition than during BL runs. As shown in Figure 5, the median rating for the PT condition was 7 or “extremely good”, whereas the BL median score was 5. Controllers generally believed that the elimination of runway crossings better enabled them to smoothly transition aircraft to their respective gates and/or to the runways. This was particularly true when taxiing turboprops to 13L. Controller comments indicated that during PT conditions they felt workload was lighter and aircraft flows were “smooth and steady.”

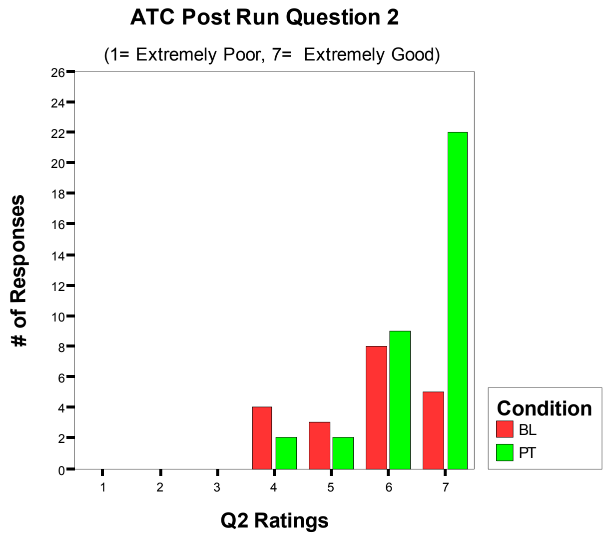


Condition	n	Median
BL	19	5
PT	33	7

Figure 5. Q1- Rate your ability to move aircraft “to and from the runways” during this run.

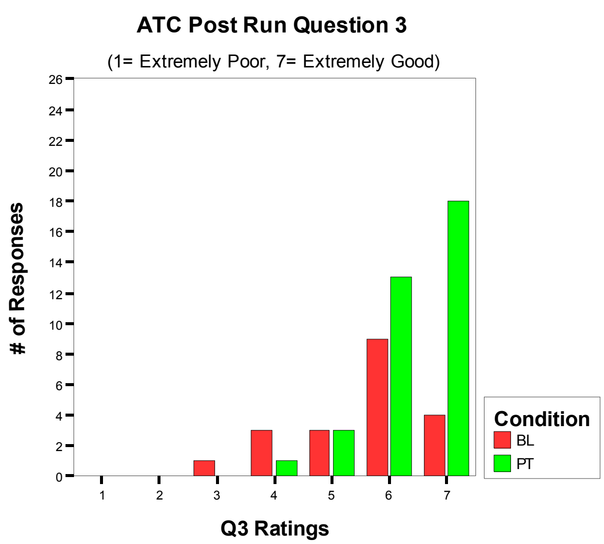
Questions 2-4

For Question 2, participants reported that their overall level of situation awareness improved as a result of PT implementation. Figure 6 shows a median response of 7 for PT conditions as compared to the BL median of 6. In their comments, they attributed this to the reduced complexity of scanning tasks that required them to ensure runways were clear to cross. With PTs they were able to re-focus their attention to other tasks because there were no runway crossing queues. This was particularly true for the Local Controllers. As shown in Figure 7, responses to Question 3 indicated that situation awareness was also perceived to improve for current aircraft locations under the PT condition (median = 7) as compared to a BL score of 6. As Figure 8 depicts, Question 4 responses to situation awareness concerning projected aircraft location did not show an improvement or degradation with PTs. Both of these ratings had a median of 6.



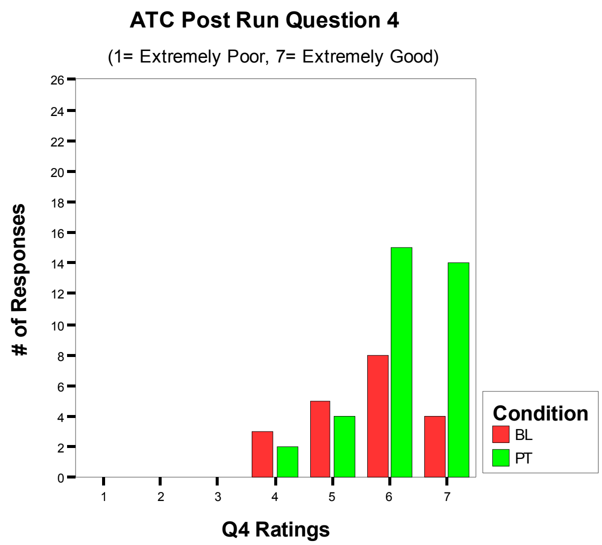
Condition	n	Median
BL	20	6
PT	35	7

Figure 6. Q2- Rate your overall level of situation awareness during this run.



Condition	n	Median
BL	20	6
PT	35	7

Figure 7. Q3- Rate your situation awareness for current aircraft locations during this run.

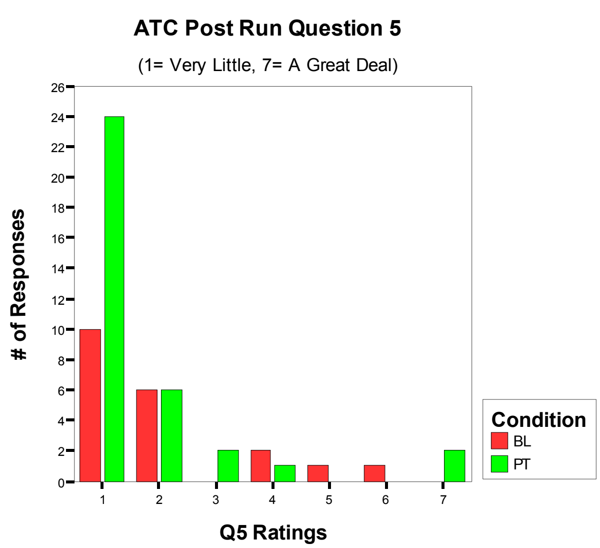


Condition	n	Median
BL	20	6
PT	35	6

Figure 8. Q4- Rate your situation awareness for projected aircraft locations during this run.

Question 5

As shown in Figure 9, the amount of controller-to-controller coordination required received a median score of 1 or "very little" for PT runs, and a median score of 1.5 for BL runs. Controllers remarked that due to the nature of the tower control environment, the need for controller-to-controller coordination is normally minimal.

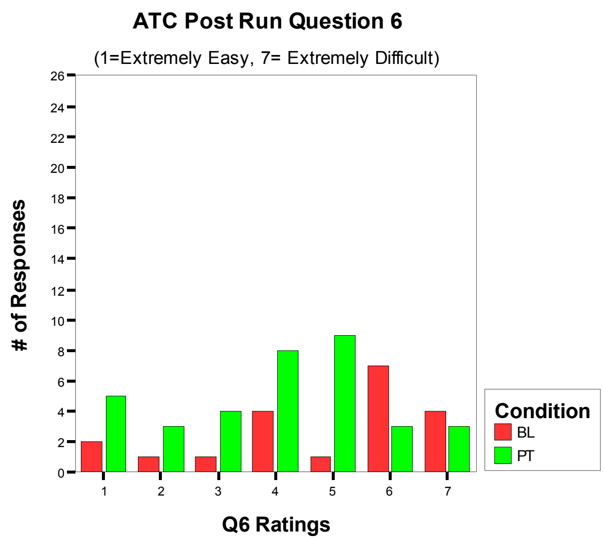


Condition	n	Median
BL	20	1.5
PT	35	1

Figure 9. Q5- How much coordination was required with other controllers during this run?

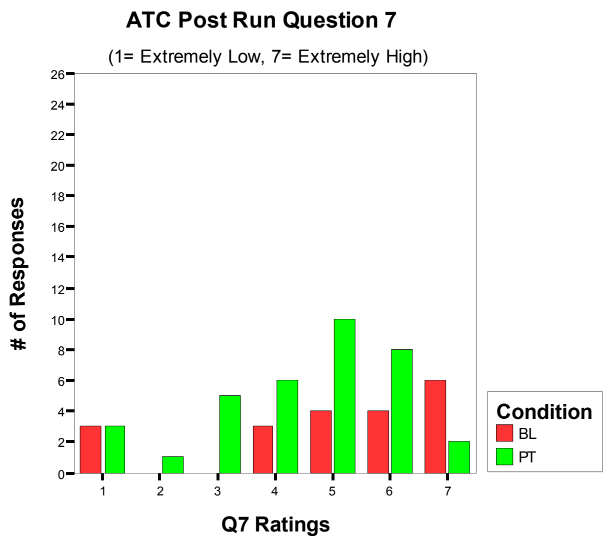
Questions 6-7

Responses to Question 6 show that ATC participants generally perceived the BL runs to be more difficult than PT runs. As shown in Figure 10, the median score for BL difficulty was 6, whereas the median for PT difficulty was 4. Figure 11 shows that the ratings of traffic complexity from Question 7 remained fairly stable for both BL and PT runs (median = 5.5 and median = 5, respectively) indicating that the complexity was perceived as moderate to high for all runs. It is interesting to note that these two questions had responses that ranged from 1 to 7 over the course of the demonstration indicating that different controllers experienced varying levels of difficulty and complexity. The runs were all built with the same or similar traffic, therefore this could be due to several things such as differences in roles and responsibilities between the positions, or simply varying opinions on the meaning of "difficult and complex."



Condition	n	Median
BL	20	6
PT	35	4

Figure 10. Q6- Rate the difficulty of this run.

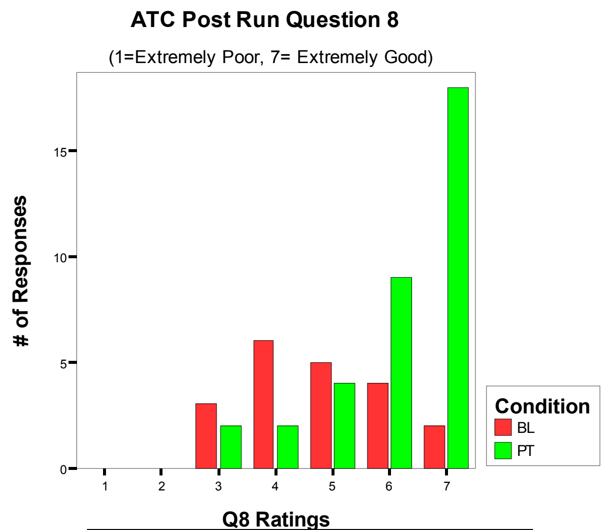


Condition	n	Median
BL	20	5.5
PT	35	5

Figure 11. Q7- What was the level of traffic complexity under your control during this run?

Question 8

Controllers believed that the PT operations were more efficient than the BL condition. PT efficiency was rated as "extremely good," with a median score of 7 as shown in Figure 12. BL runs were perceived as less efficient with a median score of 5, indicating acceptability somewhat above average. PT ratings were consistent with recorded comments that indicated the controllers felt PTs eased operational demands, improved situation awareness by reducing the complexity of scanning activities, provided for a smooth flow of traffic, decreased workload demands, and allowed for more effective strategies to be implemented (e.g., sequencing departures more efficiently in order to increase departure rates). It is interesting to note the distribution of responses once again. Both sets of responses actually had a wide distribution on the rating scale, but BL ratings were more evenly distributed from 3 to 7, whereas PT ratings swayed more prominently to the higher rakings.

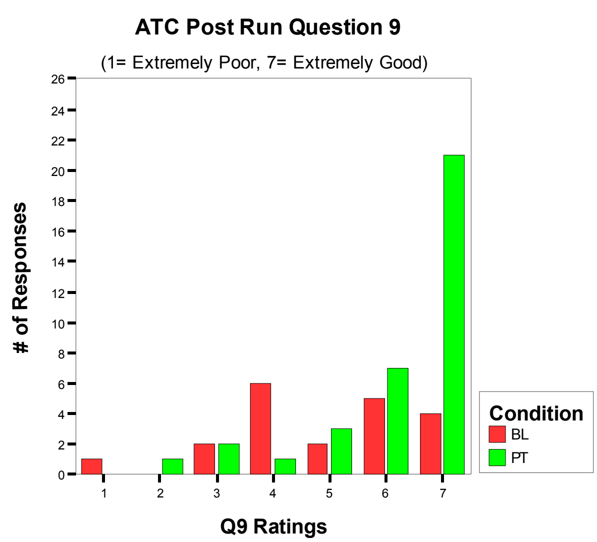


Condition	n	Median
BL	20	5
PT	35	7

Figure 12. Q8- How would you rate the overall level of efficiency of this operation?

Question 9

Controllers rated pseudo-pilot performance regarding their response to control instructions during the demonstration. Figure 13 shows that they rated a median score of 7 (extremely good) for the PT condition, and a median score of 5 (moderate to high) for the BL condition. The decline in scores from PT to BL could be attributed to the fact that fewer readbacks and controller commands were required in the PT environment. Controllers commented that they felt the pseudo-pilots did a very good job, overall.



Condition	n	Median
BL	20	5
PT	35	7

Figure 13. Q9- Rate the performance of the pseudo-pilots in terms of their responding to your control instructions, providing readbacks, etc.

3.1.1.2 ATC Post-Demonstration Questionnaires

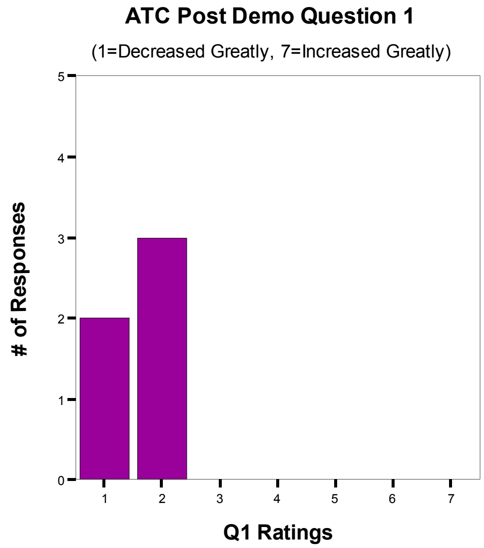
Post-Demonstration Questionnaires were administered to participating controllers at the conclusions of the demonstration. All of the controllers believed PTs would be advantageous to implement at DFW, and the demonstration provided a good representation of operations. Table 4 provides a summary of the questions and results. More detailed results and summaries for individual questions (or groups of questions) follow.

Table 4. ATC Post Demonstration Questionnaire Summary

	Question	n	Median	Scale
1	What effect, if any, did the new PTs have on the amount of frequency communications?	5	2	1= decreased greatly 7= increased greatly
2	Did your communication strategies change when you were able to utilize the PTs?	5	6	1= not at all 7= a great deal
3	What effect, if any, did the PTs have on your control strategies?	5	6	1= negative effect 7= positive effect
4	Based upon your experience in the demonstration, do you feel that adding the PTs improves operations at DFW?	5	7	1= not at all 7= a great deal
5	Rate the realism of the overall demonstration experience compared to actual ATC operations.	5	6	1= extremely unrealistic 7= extremely realistic
6	Rate the realism of the simulated hardware compared to actual equipment.	5	5	1= extremely unrealistic 7= extremely realistic
7	Rate the realism of the simulated software compared to actual functionality.	5	5	1= extremely unrealistic 7= extremely realistic
8	Rate the realism of the simulated traffic runs compared to actual National Airspace System (NAS) traffic.	5	4	1= extremely unrealistic 7= extremely realistic
9	Rate the realism of the simulated airport compared to the actual airport.	5	5	1= extremely unrealistic 7= extremely realistic

Question 1

Figure 14 shows controllers perceived that PTs reduced the amount of frequency communications in comparison to the BL scenarios. Their median response was 2, indicating a marked improvement. This rating is consistent with verbal feedback provided by the controllers. Along with several comments about reduced frequency communications, one controller felt "workload and frequency congestion was lower due to reductions in hold-short instructions and readbacks." Furthermore, controllers reported that PTs eliminated the need for calls to turboprops from the GE1 position.

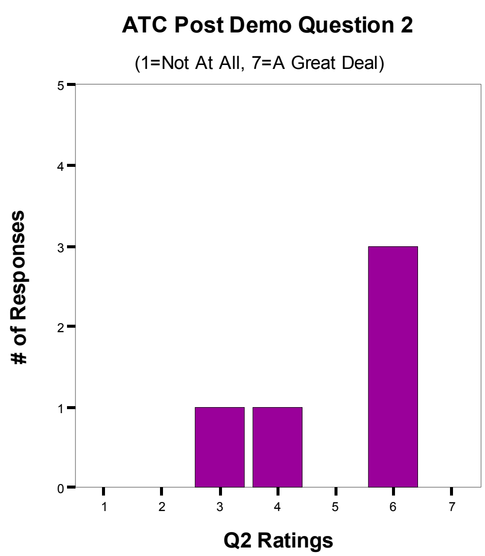


n = 5	**Median** = 2

Figure 14. Q1-. What effect, if any, did the new PTs have on the amount of frequency communications?

Question 2

A median response of 6 indicated that controllers felt that communication strategies changed quite a bit when PTs were available for use, as shown in Figure 15. However, no feedback was provided to specify how, in fact, they had changed. Inferences can be made that fewer controller-to-pilot transmissions and less frequency congestion allowed for more efficient communication strategies.

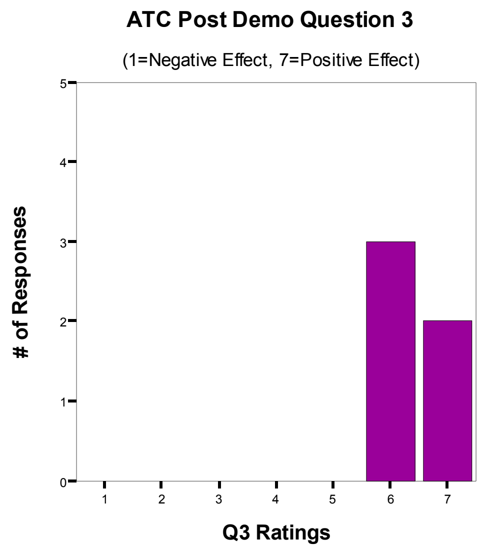


n = 5	**Median** = 6

Figure 15. Q2- Did your communication strategies change when you were able to utilize the PTs?

Question 3

As Figure 16 depicts, participant responses to whether PTs imposed positive or negative changes in control strategies resulted in a median response of 6, indicating that controllers believed PTs had an overall positive effect. Controller comments revealed that they felt they were able to increase departure rates because the need for 'gapping' for runway crossings was eliminated. The controllers reported that without gapping restraints they were able to sequence aircraft more efficiently, resulting in more 'nose-to-tail' departures. In addition, the elimination of runway crossings and the resulting ease of taxiing aircraft to their destinations (particularly for turboprops going to 13L) also improved control strategies.

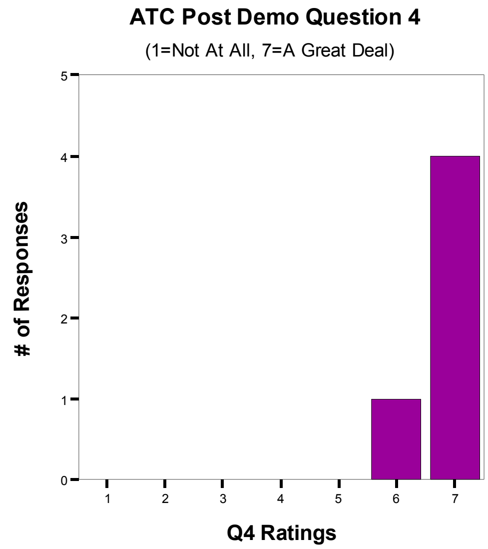


n=5	**Median**=6

Figure 16. Q3- What effect, if any, did the PTs have on your control strategies?

Question 4

Nearly all controllers thought that adding PTs improved operations at DFW "a great deal," which was a median response of 7, as depicted in Figure 17. Controllers further felt that PTs reduced frequency communications and that the operation was much smoother and less work intensive. In their opinion, the elimination of aircraft crossings reduced workload demands, decreased scanning complexity, and allowed controllers to sequence departures more efficiently in order to increase departure rates. Common comments were that PTs offered "greater efficiency", created a "smooth and steady" environment, and "cut workload in half."

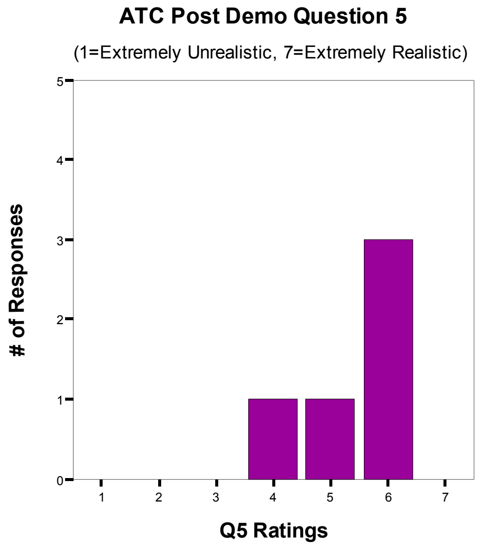


n=5	**Median**=7

Figure 17. Q4- Based upon your experience in the demonstration, do you feel that adding the PTs improves operations at DFW?

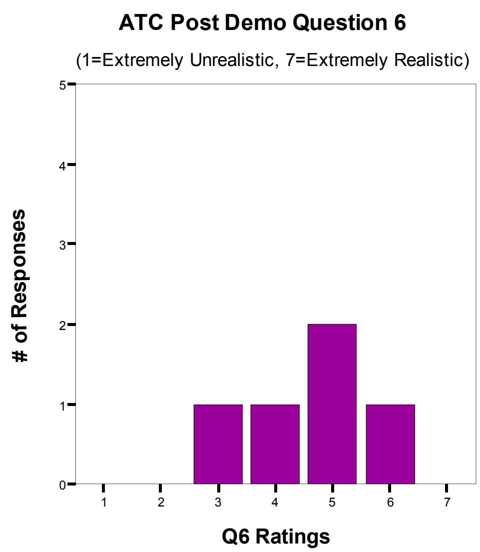
Questions 5-9

Question 5 realism ratings for the overall demonstration ranged from 4 to 6, as shown in Figure 18. The median response from controllers was a 6, on the high end of realistic representation. Questions 6 and 7 addressed the realism of hardware and software components, which received a median score of 5 (moderate to high realism), as did the realism of the simulated airport environment (Question 9). The traffic sample realism ratings addressed in Question 8 were not as favorable; the median response for simulated traffic runs compared to actual NAS traffic was 4. Controller comments indicated that the lower scores were due to some of the following difficulties: Controllers had some difficulty in discriminating the types of the most distant aircraft, largely due to the resolution of the screens. One controller's opinion was that increased traffic contributed to the problem. (Note: Traffic was intentionally increased by 20 to 30% to emulate future demand levels). Another confounding difficulty reported by the controllers was that pilots did not respond to crossing clearances as quickly as they would be able to in actual conditions. They thought that large workload demands on pseudo-pilots (who were "flying" multiple aircraft at one time), unrealistic repetition of controller clearances, and increased calls contributed to crossing delays. Controllers felt these complications might skew the BL run data, making them less representative of actual operations. In addition, the ASDE produced more clutter than actual operations, making the screen less readable and more confusing to the controllers. Controllers developed a strategy to enlist GE3's assistance by writing down the call signs for arrivals coming off the PTs for GE2. Figures 18 through 22 depict the controller's responses to Questions 5 through 9.



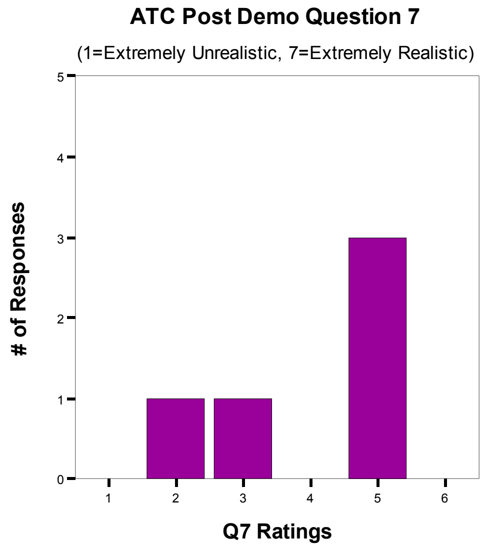
n=5	**Median**=6

Figure 18. Q5- Rate the realism of the overall demonstration experience compared to actual ATC operations



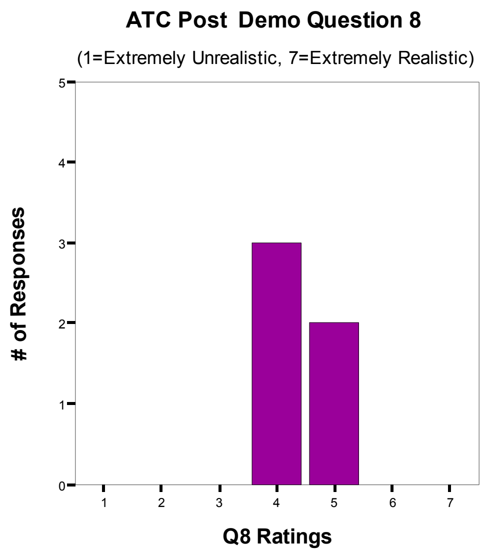
n=5	**Median**=5

Figure 19. Q6- Rate the realism of the simulated hardware compared to actual equipment.



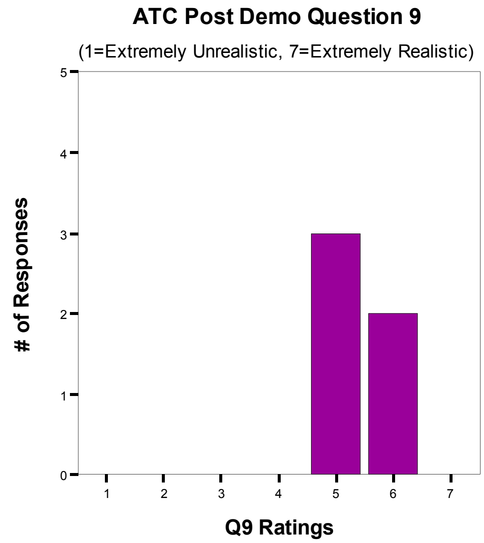
n=5	**Median**=5

Figure 20. Q7- Rate the realism of the simulated software compared to actual functionality.



n=5	**Median**=4

Figure 21. Q8- Rate the realism of the simulated traffic runs compared to actual NAS traffic.



n=5	Median=5

Figure 22. Q9- Rate the realism of the simulated airport compared to the actual airport

3.1.2 Pilot Results

A total of seven pilots participated in the DAPT Demonstration at the CVSRF. All pilots were asked to complete a Biographical Questionnaire to provide researchers with information about their range of skill and other attributes. The results indicated that pilot participants varied widely in terms of demographics, skill levels, and experience. Of the seven participants, five were active Federal Aviation Regulations (FAR) Part 121 pilots. The remaining two inactive pilots held administrative positions and had a vested interest in PT operations. Participant ages ranged from 33 to 56, and all were male. The experience of the part 121 pilots ranged from 0 to 600 total hours experience in the past 12 months. Time as commercial and military aircraft pilots ranged from 0 to 30 years. In addition to demographic information, pilots were asked to rate their skill levels, current level of stress, and level of motivation to participate in the study using Likert scales ranging from 1 to 7 (anchors were adjusted as appropriate). Pilots' self-assessed skill levels ranged from 2 to 7 (1 = *Not Skilled*, 7 = *Extremely Skilled*). Their level of stress ranged from 2 to 4 (1 = *Not Stressed*, 7 = *Extremely Stressed*) indicating that outside stressors should not have affected the pilots' ability to effectively participate in the demonstration. All reported they were largely motivated to participate in the study with scores ranging from 4 to 7 (1 = *Not Motivated*, 7 = *Extremely Motivated*).

Pilots were encouraged to experience their three "views" outlined in the test plan, specifically, pilot-on-taxi, pilot-on-arrival, and pilot-on-departure. In addition, the pilot community had specific concerns about aircraft landing overhead of taxiing perimeter traffic and aircraft departing overhead of taxiing perimeter traffic. To alleviate these concerns, all participating pilots requested views of a "worst case" scenario for the pilot takeoff view, specifically an engine loss at maximum gross weight takeoff. Participants were reportedly comfortable that traffic cleared PTs by several hundred feet on departure. The pilots also set out to ease concerns regarding the clearance between aircraft landing over the Northeast Perimeter Taxiway and the aircraft taxiing on the PT. To experience this perspective, they "froze" the B744 simulator directly above the northern perimeter on the 17C glideslope during final approach to Runway 17C. Then, they switched viewpoints and froze as a taxiing aircraft directly below the approaching aircraft so they could experience overhead crossings. From the perspective of the aircraft taxiing on the PT, participants noted the height of the arriving aircraft above them. They also noted the clearance between arriving aircraft on both 17C and 17R and the PTs. Pilots felt that adequate distance existed between the aircraft taxiing on the PTs and landing traffic. As a whole, all pilot participants were satisfied and comfortable with what they observed. One participant did comment he thought that despite the adequate distance between aircraft, passengers and pilots alike may need to adjust to the new experience of aircraft passing overhead.

3.1.2.1 Pilot Debrief Comments

All pilots reported being satisfied that the goals of the demonstration were met. Two of the seven were disappointed that FFC and CVSRF were not integrated, whereas the remaining five reported that integration would have deprived them of more beneficial use of their time in the simulator. All pilots believed that the PTs would be an improvement to current operations in terms of efficiency and safety, but were awaiting data analyses results to confirm. Several participants said they felt that even if taxi times were identical between BL and PT conditions, PTs would eliminate risks and decrease controller workload, making a safer and more efficient operation. The general perception was that PTs would save both fuel and time. Consensus was that controller and pilot workload and communications would also benefit through less radio traffic and a reduction in hold-short instructions.

In general, the pilots all held positive and confident opinions about the benefits of adding PTs. Some pilots also gave their opinions on building the PTs. For example, one pilot expressed that he would like PTs sooner than several years from now. Another pilot felt that the "virtual elimination of runway incursions justifies the expense," whereas another speculated that it would be difficult to justify the expense and complications of building the PTs in today's environment.

The majority of the pilot participants expressed positive comments, not only about the high fidelity and overall impressions of the demonstration, but also concerning the ramifications of the demonstration. Based on their experience in the demonstration, the pilots believed the PT concept may be of benefit to other facilities as well.

3.1.2.2 Pilot End-of-Day Questionnaire Ratings

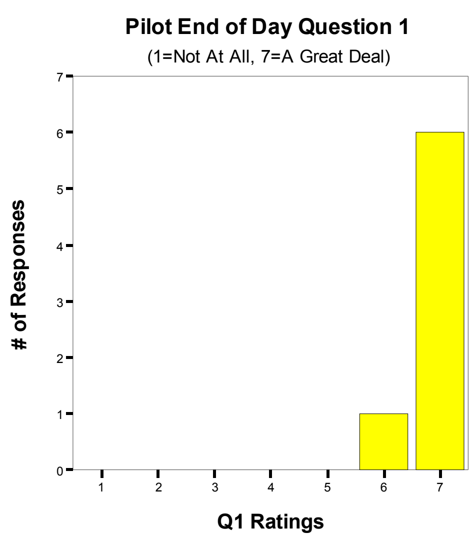
End-of-Day Questionnaires were administered to participating pilots at the end of each demonstration day (pilots typically participated for 1 day). In general, pilots believed PTs would be advantageous to implement at DFW and that the demonstration was a good representation of operations. Table 5 provides a summary of the questions and results. More detailed results and summaries for individual questions (or groups of questions) follow.

Table 5. Pilot End of Day Questionnaire Summary

	Question	n	Median	Scale
1	Based upon your experience in the demonstration, do you feel that adding the **PTs improves operations** at DFW?	7	7	1= not at all 7= a great deal
2	Rate the **realism of the overall demonstration experience** compared to actual ATC operations.	7	5	1= extremely unrealistic 7= extremely realistic
3	Rate the **realism of the simulated hardware** compared to actual equipment.	7	6	1= extremely unrealistic 7= extremely realistic
4	Rate the **realism of the simulated software** compared to actual functionality.	7	5	1= extremely unrealistic 7= extremely realistic
5	Rate the **realism of the simulated traffic runs** compared to actual NAS traffic.	7	7	1= extremely unrealistic 7= extremely realistic
6	Rate the **realism of the simulated airport** compared to the actual airport.	7	6	1= extremely unrealistic 7= extremely realistic

Question 1

Figure 23 shows a median score of 7, which indicated that pilots felt adding PTs would improve operations at DFW "a great deal." This is consistent with the positive comments expressed during debrief sessions. Pilots unanimously felt that PTs would not only improve the efficiency of DFW, but would also reduce the potential for runway incursions and enhance safety and airline performance rates.

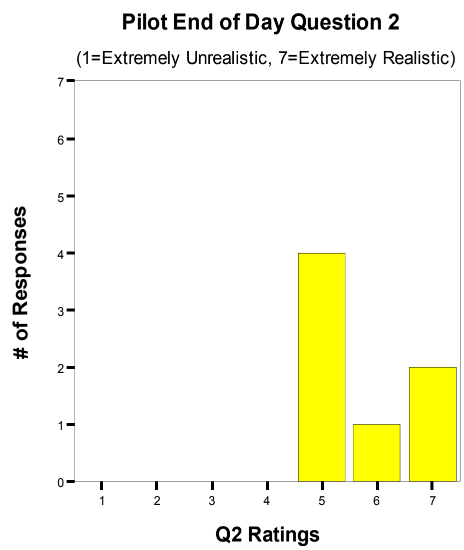


n=7	**Median**=7

Figure 23. Q1- Based on your experience in the demonstration, do you feel that adding the PTs improves operations at DFW?

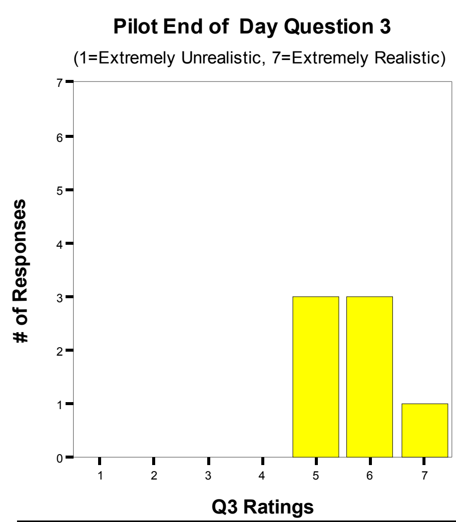
Question 2-6

Results from Question 2 indicate that pilot participants felt the overall realism of the demonstration experience was moderately to highly realistic (median = 5) in comparison to actual operations. In Question 3, hardware components received high scores for realism (median = 6), whereas software received moderate to high scores (median = 5) in Question 4. The traffic sample realism ratings addressed in Questions 5 and 6 were favorable. Pilots felt that the traffic runs were extremely realistic (median = 7), and that the simulated airport environment was highly realistic (median = 6). Figures 24 through 28 depict pilots' responses to Questions 2 through 6.



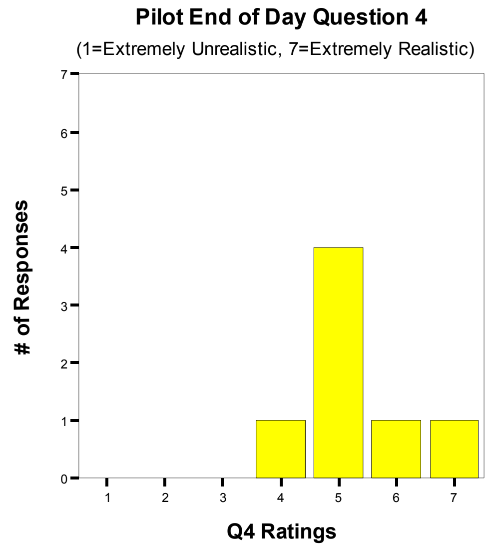
n=7	**Median**=5

Figure 24. Q2- Rate the realism of the overall demonstration experience compared to actual operations.



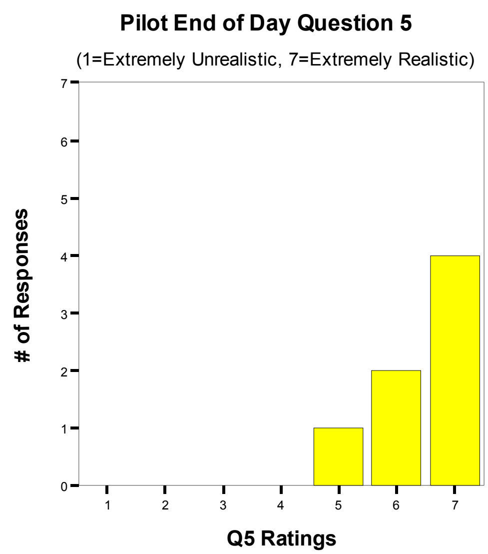
n=7	**Median**=6

Figure 25. Q3- Rate the realism of the simulated hardware compared to actual equipment.



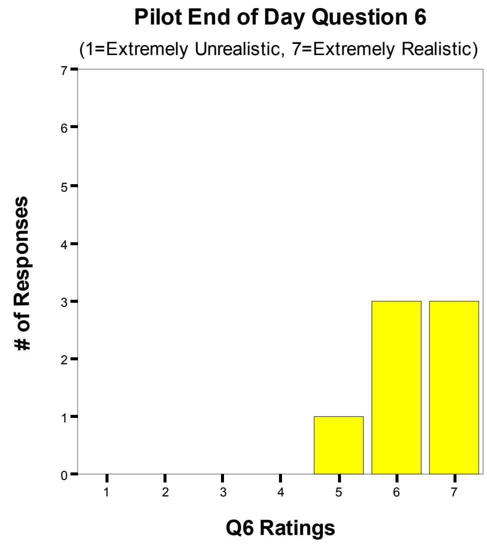
n=7	Median=5

Figure 26. Q4- Rate the realism of the simulated software compared to actual functionality.



n=7	Median=7

Figure 27. Q5- Rate the realism of the simulated traffic runs compared to actual NAS traffic.



n=7	**Median**=6

Figure 28. Q6- Rate the realism of the simulated airport compared to the actual airport.

3.2 Subjective Results Summary

The subjective data collected from participating controllers and pilots indicated that the primary objective of the exercise was met. That is, the participants were afforded the opportunity to observe and experience the proposed airport improvements with high fidelity and realism. The controllers and pilots indicated they felt the overall demonstration realism was good. In particular, they rated the realism level of the hardware, software, traffic, and the airport as moderately high to high.

The participating controllers gave all positive feedback on the proposed new PTs. Based on their experience they unanimously indicated that PTs would improve operations at DFW. They believed that the implementation of PTs in the demonstration enabled a more efficient operation. They felt the PTs provided for a smoother flow of traffic, afforded better overall ability to move aircraft to and from the runways, improved situation awareness, and decreased workload demands. Departure rates increased and aircraft were sequenced more efficiently because the need to create ‘gaps’ for runway crossings was eliminated. Furthermore, the controllers said that the complexity of scanning activities was reduced due to the elimination of runway crossing queues. The result of this was an enhanced awareness of current aircraft locations and the opportunity to refocus attention to other tasks. They also reported their communications workload was reduced due to less frequency congestion resulting from a reduction in hold-short instructions and pilot readbacks.

Pilot participants thought the PTs improved efficiency and increased safety by reducing the potential for runway incursions. They also speculated that PTs would improve airline performance rates and reduce both pilot and controller workload due to less frequency congestion and a reduction in hold-short instructions.

3.3 Objective Data

Objective data related to arrival and departure information and voice communications were collected. To allow for exploring the effect of adding PTs to DFW operations, all data and results are presented and compared by condition (BL or PT). Table 6 summarizes the data presented.

Table 6. Objective Data

Data Type	Measured by Condition
Number of times PTs are used	Overall
West side departures and arrivals	Overall, by bridge
Arrival rate / hour	Overall, by runway
Number of arrivals	Overall, by runway, 10-min increments
Inbound taxi duration	Overall, by runway
Arrival runway occupancy time	Overall, by runway
Inbound stops / hour	Overall
Inbound stop durations	Overall
Active runway crossings	Overall, by runway, 10-min increments
Active runway crossings / hour	Overall
Departure rate / hour	Overall, by runway
Number of departures	Overall, by runway, 10-min increments
Outbound taxi duration	Overall, by runway
Departure runway occupancy time	Overall, by runway, (for behind a heavy, and not behind a heavy)
Outbound stops / hour	Overall
Outbound stop durations	Overall
Controller & pilot communications	Includes transmission duration and word count

3.3.1 Arrival and Departure Data

The following sections present departure and arrival information obtained from the demonstration. The data are presented for each condition (BL and PT) overall and by runway.

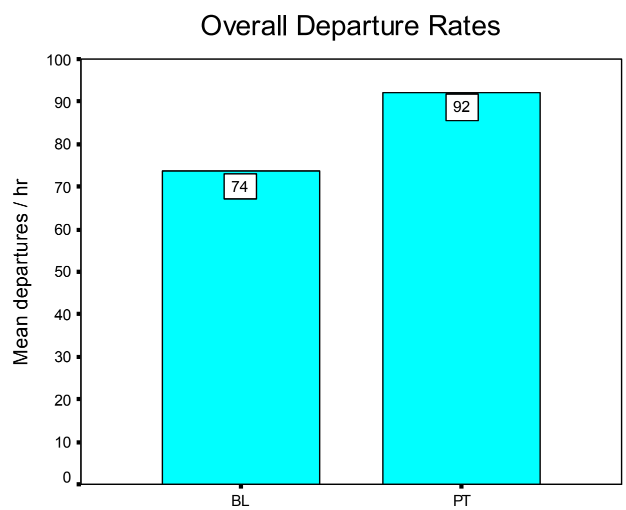
By design, 100% of arrivals and departures that flew in runs with PTs utilized the new PTs. Of course, the new PTs did not exist in the BL condition, and therefore, they were not used in these runs.

As previously mentioned, the demonstration emulated East-side tower operations; however, elements of West-side traffic were included for realism. Bridge traffic and arrivals and departures affecting the West-side were built into each run. Table 7 shows the average number of departures and arrivals per hour that taxied to/from the West side of the airport and the respective bridges they crossed.

Table 7. Arrivals and Departures that Crossed to/from the West-side

Start	Bridge Crossed	To	BL (avg/hr)	PT (avg/hr)
East departures	Z	West	16	16
East departures	B	West	5	6
West departures	Y	East	10	13
West arrivals	A	East	46	46
West arrivals	Y	East	4	4
East arrivals	B	West	9	9

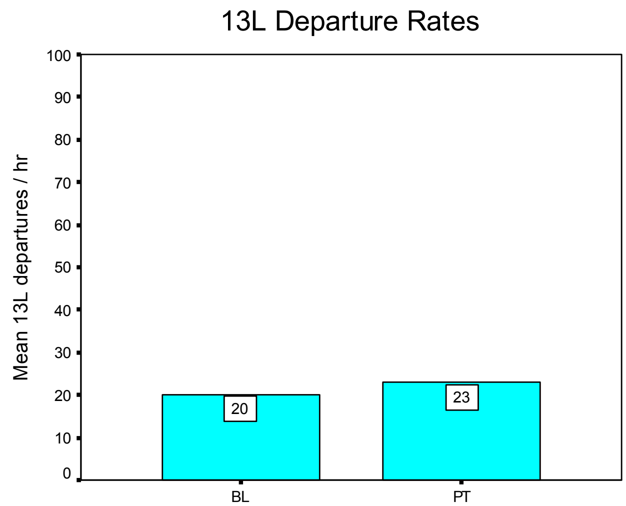
Mean arrival rates for BL and PT conditions remained consistent at about 79 aircraft per hour. However, Figure 29 indicates a substantial increase of about 18 departures per hour on average (or 24% relative increase) in the departure rate for the PT condition.



% Change BL to PT	+ 24 %

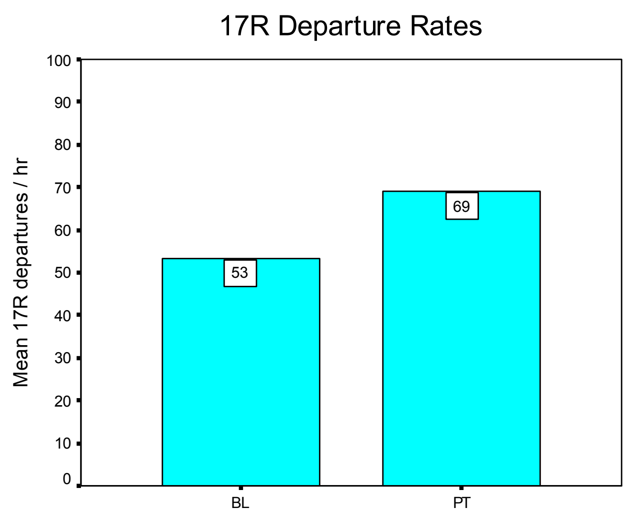
Figure 29. Overall departure rates.

When examined by runway, both 17L and 17C arrival rates were consistent at about 39 to 40 aircraft per hour. There was an average increase of three departures per hour on 13L with PTs (a 15% relative increase), however, the difference seen in the overall departure rate was mostly due to the substantial improvement on 17R, which increased 16 departures per hour on average (a 30% relative increase). Figures 30 and 31 illustrate these findings.



% Change BL to PT	+ 15 %

Figure 30. 13L departure rates.



% Change BL to PT	+ 30 %

Figure 31. 17R departure rates.

Tables 8 and 9 present average counts of arrivals and departures by runway in 10-minute increments for each condition. These tables allow for inspection by smaller units of time and these data also show increased PT departure rates over BL.

Table 8. BL Arrival/Departure Data in 10-Minute Increments

	17C arr mean #	17L arr mean #	13L dep mean #	17R dep mean #	TOTAL	
					arr mean #	dep mean #
0-10 min	6	6	4	9	12	13
10-20 min	7	7	4	10	14	13
20-30 min	8	8	3	9	16	12
30-40 min	6	6	5	8	12	12

- **Numbers in cells are averages across runs and are rounded to whole numbers.**
- **n varies from 4 - 6 for each cell.**

Table 9. PT Arrival/Departure Data in 10-Minute Increments

	17C arr mean #	17L arr mean #	13L dep mean #	17R dep mean #	TOTAL	
					arr mean #	dep mean #
0-10 min	6	6	5	12	12	18
10-20 min	7	7	4	13	14	18
20-30 min	8	8	5	11	16	16
30-40 min	6	6	1	12	12	13

- **Numbers in cells are averages across runs and are rounded to whole numbers.**
- **n varies from 5 - 7 for each cell.**

Inbound taxi duration for this demonstration was measured as presented in Table 10.

Table 10. Description of Inbound Taxi Duration

Lands on:	Taxis to:	Inbound Taxi Duration	
		Start	**End**
East	East	Touchdown	Upon reaching Spot (i.e., entrance/exit apron point)
East	West	Touchdown	~2/3 across B bridge
West	East	West end of A or Y Bridge	Upon reaching Spot

As can be seen in Table 11, the average inbound taxi duration per aircraft increased by about 2:07 minutes (or 18%) from the BL to the PT condition. Looking at the data by runway, it appears that the increase was exclusively due to the marked increase in 17C taxi duration times (4:56 minutes or 54% increase over BL). In fact, during PT conditions, 17L taxi durations decreased by about 1:16 minutes or 8% on average.

Table 11. Inbound Taxi Duration

ARRIVALS	**BL mean n=4 runs (min:sec)**	**PT mean n=7 runs (min:sec)**	**Change from BL to PT**	
			(min:sec)	**% Change**
OVERALL				
Inbound taxi duration /aircraft	11:52	13:59	+ 2:07	+ 18 %
BY RUNWAY				
17C inbound taxi duration /aircraft	9:12	14:08	+ 4:56	+ 54 %
17L inbound taxi duration /aircraft	15:07	13:51	- 1:16	- 8 %

- Numbers in cells are averages across runs.

Outbound taxi duration for this demonstration was measured as presented in Table 12.

Table 12. Description of Outbound Taxi Duration

Departs from:	**Taxis to:**	**Outbound Taxi Duration**	
		Start	**End**
East	Runways 17R, 13L	Upon reaching Spot	Takeoff (airborne)
East	Runway 18L	Upon reaching Spot	~2/3 across B or Z bridge
West	Runway 17R	West end of Z bridge	Takeoff (airborne)

Table 13 indicates that the average outbound taxi duration and associated runway occupancy time (when behind a heavy jet) showed substantial improvement with PTs compared to the BL conditions, decreasing on average 4:28 minutes (27%) and 41 seconds (44%), respectively. In addition, taxi-out runway occupancy time (when not behind a heavy) showed a lesser improvement of about a 2 second decrease (or 4%) with PTs. Examining the data by runway indicated that with PTs, 17R showed the most improvement in outbound taxi duration times (6:19 minutes or a 32% relative decrease), with 13L gaining a smaller improvement (41 seconds or a 7% decrease). Heavy aircraft do not depart off of 13L, therefore the observed 44% decrease in runway occupancy time when behind a heavy was due exclusively to the decreased time spent on 17R. Also, when not behind a heavy, 17R runway occupancy times decreased about 5 seconds (or 12%) with PTs and 13L times decreased by an average of 3 seconds or about 4%.

Table 13. Outbound Taxi Duration and Departure Runway Occupancy Data

DEPARTURES	BL mean n=4 runs (min:sec)	PT mean n=7 runs (min:sec)	Change from BL to PT	
			(min:sec)	% Change
OVERALL				
Outbound taxi duration /aircraft	16:36	12:08	- 4:28	- 27 %
• Departure rwy occupancy time /aircraft (behind a heavy)	1:31	0:51	- 0:41	- 44 %
• Departure rwy occupancy time /aircraft (not behind a heavy)	0:51	0:49	- 0:02	- 4 %
BY RUNWAY				
13L outbound taxi duration /aircraft	9:26	8:45	- 0:41	- 7 %
• 13L departure rwy occupancy time/aircraft (behind a heavy)	n/a	n/a	n/a	n/a
• 13L departure rwy occupancy time/aircraft (not behind a heavy)	1:10	1:07	- 0:03	- 4 %
17R outbound taxi duration /aircraft	19:42	13:23	- 6:19	- 32 %
• 17R departure rwy occupancy time/aircraft (behind a heavy)	1:31	0:51	- 0:40	- 44 %
• 17R departure rwy occupancy time/aircraft (not behind a heavy)	0:41	0:36	- 0:05	- 12 %

- Numbers in cells are averages across runs.

Inbound and outbound stops and their associated durations were calculated for all aircraft in the scenarios. This included aircraft coming from and going to the West-side of the airport, as well as the aircraft originating and/or terminating on the East-side. All stops made by aircraft while taxing at any point on the airport were included. Table 14 shows that the average inbound stop rate and the duration of stops decreased substantially when PTs were available (-49% and -28% respectively). The average outbound stop rate decreased by about 14% for PTs runs, and the average duration of these stops were 29% shorter than in the BL runs on the whole.

Table 14. Aircraft Stop Rates and Duration

	BL n=4 runs	PT n=7 runs	% Change BL to PT
Inbound stops mean # / hour	293	150	- 49 %
Inbound stops mean duration /stop (sec)	72	52	- 28 %
Outbound stops mean # / hour	470	405	- 14 %
Outbound stops mean duration /stop (sec)	111	79	- 29 %

- Numbers in cells are averages across runs and are rounded to whole numbers.

The data in Table 15 present runway crossing data for BL runs. The results include mean counts per 10-minute intervals by runway and mean number of crossings per hour by runway. BL runs had an average of 154 runway crossings an hour (about 94 aircraft crossed 17R per hour and 60 crossed 17C). By design, PTs completely eliminated runway crossings at DFW in the demonstration.

Table 15. Baseline Runway Crossing Data

	17C	**17R**	**Total**
	mean #	**mean #**	**mean #**
0-10 min	13	17	29
10-20 min	8	13	20
20-30 min	11	18	29
30-40 min	12	21	34
mean # xings/hour	60	94	154

3.3.2 Communications Data

Many different measures can be analytically explored to assess the workload of a human operator in any system. The frequency and duration of controller/pilot communications are well-known major contributors to overall workload associated with ATC operations. New procedures can often affect communications by either increasing or reducing the demands placed on the operators to perform associated tasks. These effects can have a significant impact on the acceptance of a new concept.

A detailed assessment of the impact of communications workload and frequency congestion in the DAPT Demonstration is provided in this section. There are, however, potential caveats to bear in mind. When examining the communications data, it is crucial to consider that the information was derived from demonstration data (not operational data). Several things could potentially affect the data precision; for example, pseudo-pilots handled more than one aircraft at a time, controllers experienced PT operations and procedures for the first time, and the analysis itself was mostly manual (i.e., potential for human error). Keeping these issues in mind, there are many interesting observations.

BL runs in the demonstration included the four controller positions and frequencies that exist in the East Control Tower today. However, for the PT runs a new controller position was added to ground operations. The new position, GE3, was added to manage the high volume of traffic that utilized the PTs and southern portion of the airport. Table 16 depicts the frequencies emulated in the DAPT Demonstration.

Table 16. Positions and Frequencies

Controller Position	Frequency
LE1	126.55
LE2	127.5
GE1	121.65
GE2	121.8
GE3	121.6

Results of the communications data were derived from counting the number of transmissions, transmission durations, and the number of words spoken by the controllers and pilots during the demonstration. Approximately 20,500 transmissions, including over 200,000 words, were analyzed for the analyses. Because the runs were of variable lengths, some results were converted to hourly rates and then averaged across runs. Tables 17 through 19 show a summary of results including means (rounded) for each frequency and *relative* changes from the BL condition to the PT condition in terms of percentage increases and decreases. Discussion of results compares the common frequencies of the two conditions (i.e., LE1, LE2, GE1, and GE2). GE3 data were provided for informational purposes.

Table 17. Summary of Communication Results (Controllers and Pilots Combined)

Data	Statistic	Frequency				
		LE1	**LE2**	**GE1**	GE2	**GE3**
# of transmissions / hour	Mean BL	433	174	302	352	n/a
	Mean PT	338	174	275	348	207
	% Change BL to PT	- 22.0 %	- < 1 %	- 9.0 %	- 1 %	n/a
Time spent talking (% / hr)	Mean BL	58.5	30.1	42.2	53.86	n/a
	Mean PT	44.6	25.5	36.5	52.85	29.8
	% Change BL to PT	- 23.8 %	- 15.3 %	- 13.5 %	- 1.9 %	n/a
Length of transmissions (sec)	Mean BL	2.4	3.1	2.5	2.8	n/a
	Mean PT	2.4	2.7	2.4	2.7	2.7
	% Change BL to PT	- 2.1 %	- 14.3 %	- 2.4 %	- 2.5 %	n/a
Time between transmission starts (sec)	Mean BL	4.2	10.4	6.0	9.9	n/a
	Mean PT	5.4	10.4	6.7	10.0	1906
	% Change BL to PT	+ 28.6 %	+ < 1 %	+ 12.3 %	+ < 1 %	n/a
# of words / hour	Mean BL	4543	2179	2528	4563	n/a
	Mean PT	3328	1904	2337	4402	9
	% Change BL to PT	- 26.7 %	- 12.6 %	- 7.6 %	- 3.5 %	n/a
# of words / transmission	Mean BL	11	13	8.4	10.5	n/a
	Mean PT	10	11	8.4	10.4	3.8
	% Change BL to PT	- 5.7 %	- 13.1 %	+ < 1 %	- < 1 %	n/a
Speed of speech (words/sec)	Mean BL	4.4	4.3	3.5	3.9	n/a
	Mean PT	4.2	4.2	3.6	4.0	3.8
	% Change BL to PT	- 3.4 %	- 1.5 %	+ 2.8 %	+ 1.5 %	n/a

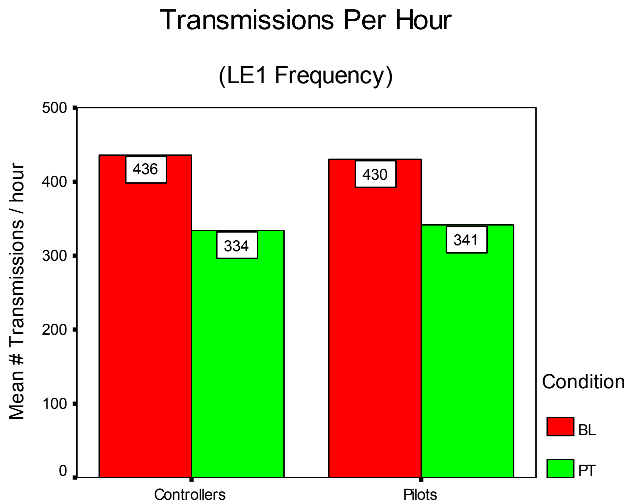
Table 18. Summary of Communication Results for Controllers (only)

Data	Statistic	Frequency				
		LE1	LE2	GE1	GE2	GE3
# of transmissions / hour	Mean BL	436	163	326	369	n/a
	Mean PT	334	162	293	363	175
	% Change BL to PT	- 23.4 %	- < 1 %	- 10.1 %	- 1.6 %	n/a
Time spent talking (% / hr)	Mean BL	35.4	17.4	24.8	32.7	n/a
	Mean PT	27.3	15.0	20.4	31.3	13.3
	% Change BL to PT	- 23.0 %	- 14.1 %	- 18 %	- 4.2 %	n/a
Length of transmissions (sec)	Mean BL	2.9	3.8	2.8	3.3	n/a
	Mean PT	2.9	3.3	2.5	3.2	2.8
	% Change BL to PT	0 %	- 14.3 %	- 8.9 %	- 3.9 %	n/a
# of words / hour	Mean BL	5778	2555	3102	4563	n/a
	Mean PT	4292	2184	2714	4402	1757
	% Change BL to PT	- 25.7 %	- 14.5 %	- 12.5 %	- 3.5 %	n/a
# of words / transmission	Mean BL	13	16	10	13	n/a
	Mean PT	13	13	9	12	10
	% Change BL to PT	- 3.2 %	- 14.9 %	- 5.0 %	- 2.5 %	n/a
Speed of speech (words/sec)	Mean BL	4.7	4.3	3.8	4.1	n/a
	Mean PT	4.5	4.1	3.9	4.2	4.0
	% Change BL to PT	- 3.7 %	- 2.9 %	+ 3.2 %	+ 1.2 %	n/a

Table 19. Summary of Communication Results for Pilots (only)

Data	Statistic	Frequency				
		LE1	**LE2**	**GE1**	**GE2**	**GE3**
# of transmissions / hour	Mean BL	430	185	278	335	n/a
	Mean PT	341	186	256	334	239
	% Change BL to PT	- 20.6 %	+ < 1 %	- 7.7 %	- < 1 %	n/a
Time spent talking (% / hr)	Mean BL	23.1	12.7	17.4	21.2	n/a
	Mean PT	17.3	10.9	17.0	21.2	16.8
	% Change BL to PT	-25.3 %	- 14.4 %	- 2.2 %	- < 1 %	n/a
Length of transmissions (sec)	Mean BL	1.9	2.5	2.3	2.3	n/a
	Mean PT	1.8	2.1	2.4	2.3	2.5
	% Change BL to PT	- 5.8 %	- 14.3 %	+ 5.5 %	- < 1 %	n/a
# of words / hour	Mean BL	3308	1802	1955	2770	n/a
	Mean PT	2365	1624	1959	2821	2054
	% Change BL to PT	- 28.5 %	- 9.9 %	+ < 1 %	+ 1.8 %	n/a
# of words / transmission	Mean BL	8	10	7	8	n/a
	Mean PT	7	9	8	8	9
	% Change BL to PT	- 10.0 %	- 10.2 %	+ 7.4 %	+ 1.2 %	n/a
Speed of speech (words/sec)	Mean BL	4.1	4.3	3.2	3.8	n/a
	Mean PT	3.9	4.3	3.3	3.8	3.6
	% Change BL to PT	- 3.3 %	- < 1 %	+ 2.2 %	+ 1.7 %	n/a

Currently at DFW, the LE1 controller talks to the greatest number of aircraft with the least amount of time to spare, resulting in the highest frequency congestion. The LE1 position is also critical because it currently experiences the greatest number of runway crossings, and consequently has the greatest potential for delays and runway incursions. Therefore, it was of particular interest to closely evaluate the frequency associated with the LE1 controller position in the demonstration. Figures 32 through 34 graphically depict observances of the transmission data (means are rounded) for this position. Inferential statistics (i.e., *t*-tests and Tests of Homogeneity) were used as appropriate to substantiate observed results.

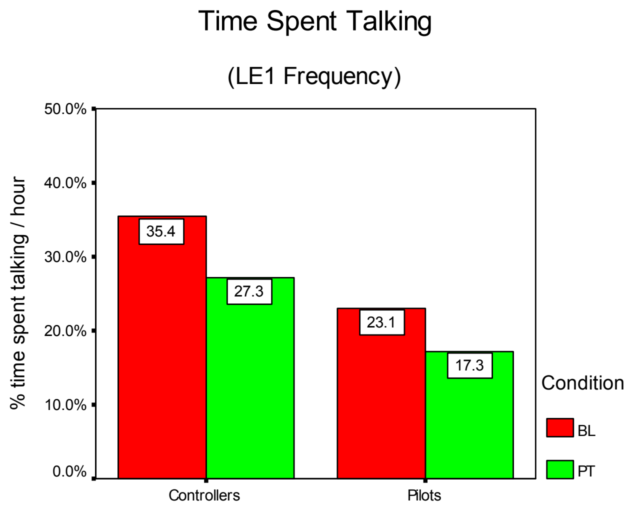


Mean BL	433
Mean PT	338
% Change BL to PT	- 22.0%

Figure 32. LE1 frequency transmissions per hour.

Table 17 and Figure 32 indicate a substantial relative reduction (-22%) from BL to PT pertaining to the average number of transmissions per hour for the LE1 frequency. A *t*-test for independent samples (equal variances assumed) confirmed the result indicating that the difference was also statistically significant (t=8.41, df=18, p<.05). Based on feedback during debrief sessions, the reduction in frequency congestion for this position was distinctly felt by the controllers. One controller commented that he thought it felt like he experienced "about half the transmissions with PTs." When considering the controllers only, the hourly number of transmissions dropped by about 23% (from 436 transmissions to 334) with PTs, which was again backed by statistical significance (t=4.97, df=8, p<.05). Average pilot transmissions amply decreased by about 21% (from 430 to 341 per hour) with the difference between conditions being statistically significant (t=7.37, df=8, p<.05).

Though Tables 17 through 19 show that LE2 and GE2 varied little between the BL and PT conditions, the frequency for GE1 had a noticeable reduction in the average number of transmissions per hour. Transmissions decreased 9% overall, 10% when listening to the controllers only, and close to 8% when examining the pilot transmissions alone.

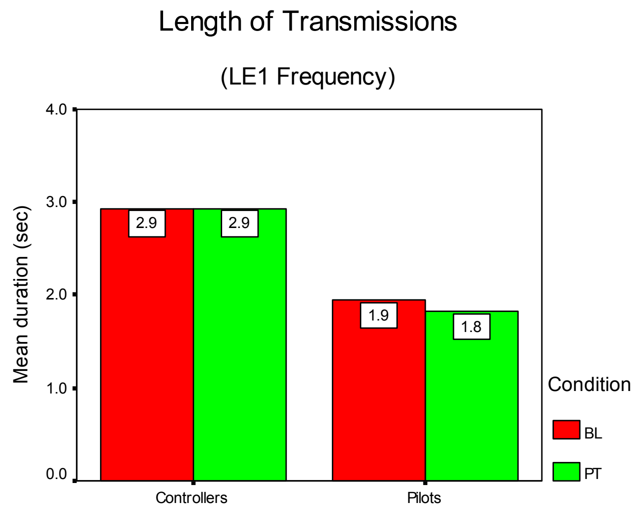


Mean BL	58.5 %
Mean PT	44.6 %
% Change BL to PT	- 23.8 %

Figure 33. LE1 frequency time spent talking.

Table 17 and Figure 33 indicate that the percentage of time the LE1 controllers and pilots talked was reduced by about 24% with PTs relative to BL. A *t*-test for independent samples (equal variances assumed) confirmed that the substantial difference was also statistically significant (t=8.409, df=18, p<.05). The time controllers (only) spent talking dropped 23% (from 35% to about 27%) with PTs as compared to BL. A *t*-test indicated the observed reduction was again statistically significant (t=3.74, df=8, p<.05). Average pilot transmissions decreased considerably by about 25% (from 23% to about 17 %) with the difference between conditions being statistically significant (t=7.78, df=8, p<.05).

Tables 17 through 19 show the other common frequencies (i.e., LE2, GE1, and GE2) also experienced noticeable differences between the BL and PT conditions. LE2 and GE1 had overall reductions of 15% and 14% respectively. However, the highest relative reduction from BL to PT for these remaining frequencies was for GE1 controllers who had an 18% decrease in the time they spent on frequency.



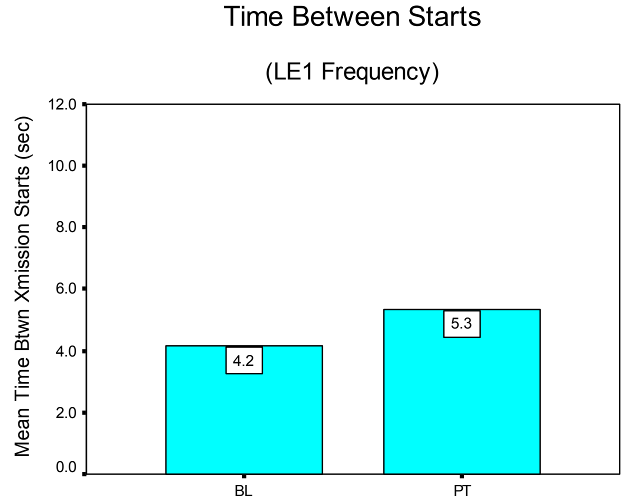
Mean BL	2.4
Mean PT	2.4
% Change BL to PT	- 2.1 %

Figure 34. LE1 frequency length of transmissions.

When considering controller and pilot communications together, Table 17 and Figure 34 do not suggest a noticeable difference for the average duration of transmissions between the BL and PT conditions. The relative decrease from BL to PT was only about 2%, which is not likely to be considered operationally meaningful. A *t*-test (equal variances assumed) designated that this result was also not statistically significant (t=1.34, df=5403, p>.05). No difference between conditions can be seen when controllers were analyzed separately, but there was a small relative decrease of about 6% for pilots when there were PTs. An average difference of about a tenth of a second is not likely to be operationally relevant as an independent measure; however, it is possible that the cumulative effect of many such small reductions collectively could relieve frequency congestion and communications workload. A *t*-test indicated the result to be statistically significant (t=3.44, df=2705, p<.05).

Table 17 shows that the ground frequencies had similar results to LE1 when considering controllers and pilots together, but LE2 demonstrated a relative decrease of transmission duration with PTs of about 14%. Table 18 shows that GE1 controllers had a 9 % decrease, but Table 19 shows that the pilots had a slight increase of about 6% in the average length of communications.

The average time between the *beginnings* of transmissions was calculated. Specifically, if the measurement of Time Between Starts was 4.2, it is interpreted that, on average, there was a new transmission that started every 4.2 seconds. Figure 35 depicts the observed Time Between Starts for transmissions on the frequency associated with the LE1 position.

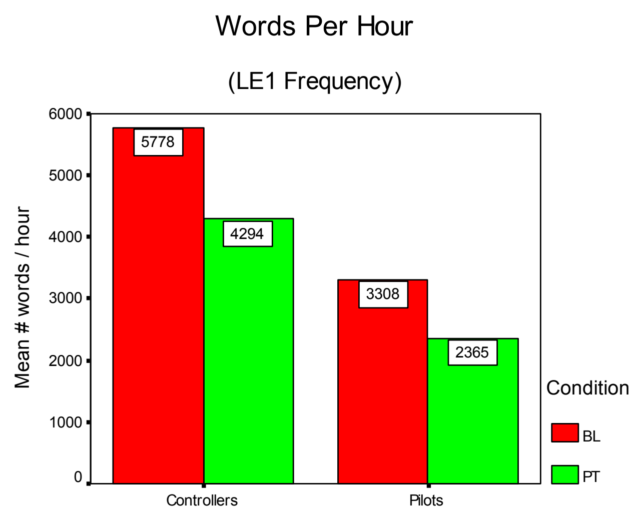


Mean BL	4.2
Mean PT	5.4
% Change BL to PT	+ 28.6 %

Figure 35. LE1 frequency time between transmission starts.

Table 17 and Figure 35 indicate that the average time between the beginnings of transmissions was stretched further by about 29% for PT runs. This result is evidence that the participants had longer breaks between frequency communications. A *t*-test (equal variance assumed) verified that the difference was also statistically significant (t=-5.43, df=8, p<.05).

Figures 36 though 38 indicate observances of word data (means are rounded).

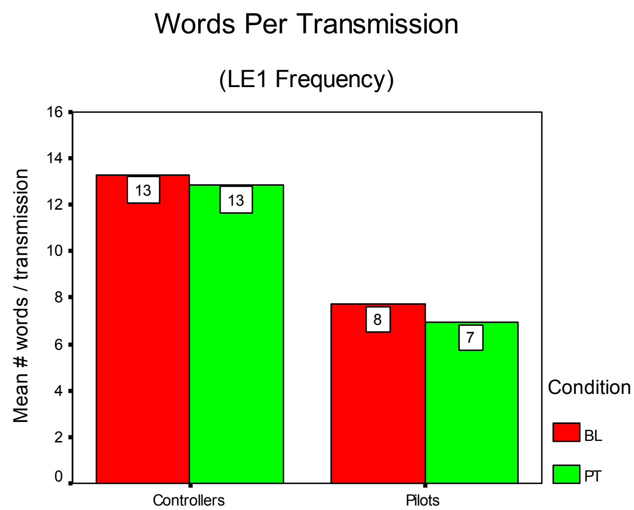


Mean BL	4543
Mean PT	3328
% Change BL to PT	- 26.7 %

Figure 36. LE1 frequency number of words per hour.

As can be seen in Table 17 and Figure 36, the average number of overall words per hour for the LE1 frequency was reduced by 26% with PTs relative to BL. A *t*-test for independent samples (equal variances assumed) confirmed the result indicating that the difference was also statistically significant (t=2.19, df=18, p<.05). These findings are consistent with comments from the controllers during debrief sessions. For example, they indicated that they were able to use less verbiage because they did not have to concentrate on crossings or rely on pilot readbacks for hold-short instructions. When evaluating the data for controllers only, the hourly number of words dropped by about 26% (from 5778 words to 4292) with PTs, which was again backed by statistical significance (t=3.74, df=8, p<.05). Average pilot words decreased considerably by about 29% (from 3308 to 2365 per hour) with the difference between conditions being statistically significant as well (t=7.93, df=8, p<.05).

Tables 17 through 19 show that LE2 also experienced a notable difference overall between the words spoken in PT versus the BL conditions (about 13% relative reduction). Looking at controllers by themselves, LE2 and GE2 had noteworthy reductions in the words spoken (about 15% and 13% respectively). Examining pilots by themselves, only LE2 showed a noticeable difference of about a 10% relative reduction with PTs.

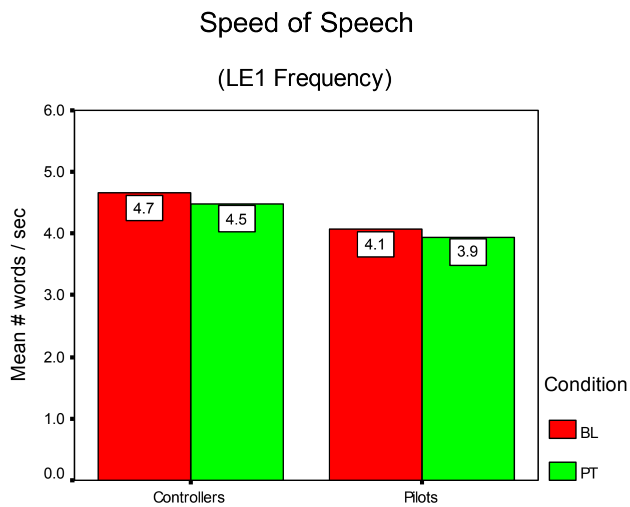


Mean BL	11
Mean PT	10
% Change BL to PT	- 5.7 %

Figure 37. LE1 frequency number of words per transmission.

When assessing controller and pilot communications together, Table 17 and Figure 37 reveal a rather small reduction in the average number of words per transmissions from BL to PT operations. The relative decrease was only about 6% per transmission, but the cumulative effect of such a subtle reduction could collectively have a favorable influence on overall frequency congestion. A *t*-test (equal variances assumed) designated that this result was, in fact, statistically significant (t=4.25, df=5403, p<.05). An even smaller difference between conditions was seen when controllers were analyzed separately. The 3% decrease with PTs for controllers seems quite minor and could be due to "noise" in the data. The *t*-test (equal variances not assumed) indicated the result was not statistically significant (*t*=1.84, *df*=2652*, p*>.05). However, there was about a 10% decrease for pilots when there were PTs, which was statistically significant (*t*=6.10, *df*=2560, *p*<.05).

Table 17 shows that the ground frequencies had negligible results when considering controllers and pilots together, but LE2 demonstrated a relative decrease with PTs of about 13%. The controller data in Table 18 show that LE2 controllers had a 15% decrease, and Table 19 shows that the pilots in the PTs conditions had about a 10% relative decrease in the average number of words per transmission. Interestingly, the ground frequencies indicated small increases in the number of words per transmission for pilots.



Mean BL	4.4
Mean PT	4.2
% Change BL to PT	- 3.4 %

Figure 38. LE1 frequency speed of speech.

Table 17 and Figure 38 do not suggest a consequential difference for speed of speech between the BL and PT conditions regardless of whether the data for the LE1 frequency were examined overall or with controllers and pilots separated. The relative decreases from BL to PT ranged from only about 3 to 4%, results that at first glance do not appear to be operationally meaningful. Interestingly though, *t*-tests (equal variances assumed) indicated that all three differences were statistically significant (controllers and pilots combined *t=6.22, df=5403, p<.05;* controllers only *t=5.16, df=2696, p<.05;* pilots only *t=3.63, df=2705, p<.05).* This finding is difficult to explain, but it is possible that because the sample size for this particular data was so large and consistent, even such a minute difference could produce significant results.

Tables 17 shows that the LE2 frequency also had a very small, likely negligible, decrease when considering controllers and pilots together. However, the ground positions actually demonstrated slight increases in the words spoken per second with PTs. Looking at controllers in Table 18 and pilots in Table 19, GE1 and GE2 also showed very slight increases in their speed of speech.

3.3.3 Communications Summary

The figures and tables presented in this section suggest that controller and pilot communications for the LE1 frequency were clearly reduced with the addition of PTs. In general, there were significantly fewer transmissions made with fewer words spoken. This resulted in the controllers and pilots spending less time on frequency during the PTs conditions compared to BL. Words were also spoken slightly slower on average in PT runs. In addition to being operationally relevant, these results were also statistically significant for the LE1 frequency. Such findings were consistent with controller debrief comments; controllers felt the volume of communications was significantly reduced, and they used less verbiage because concerns about crossings and reliance on pilot readbacks were alleviated. Many of the positive data results were also apparent in the findings of the other frequencies, but generally to a lesser degree.

3.4 Objective Results Summary

The objective data resulting from the demonstration supported the participants' verbal comments. Both indicated that the PTs would improve operations at DFW if implemented.

Arrival rates for the BL and PT conditions remained consistent (by design). However, there was a substantial increase in the departure rate per hour for the PT condition (about 18 departures/hour or 24% relative increase). There was a small increase in the 13L average departure rates for PTs (about 3 departures/hour or 15% relative increase), but the difference seen in the overall departure rate was mostly due to the substantial increase in the 17R average departure rates for PTs (about 16 departures/hour or 30% relative increase).

The average inbound taxi duration increased by about 2:07 minutes (or 18%) from the BL to the PT condition. The average outbound taxi duration and associated runway occupancy time (when behind a heavy jet) showed substantial improvements with PTs compared to the BL runs, decreasing on average 4:28 minutes (27%) and 41 seconds (44%) respectively. Taxi-out runway occupancy time (when not behind a heavy) showed a lesser improvement of about 4% with PTs.

On the whole, inbound stop rates and the duration of stops decreased substantially when PTs were available (-49% and -28 % respectively). Outbound stop rates decreased by about 14% for PT runs, and the average duration of these stops were 29% shorter than in the BL runs.

BL runs had an average of 154 runway crossings an hour (about 94 aircraft crossed 17R per hour and 60 crossed 17C). By design, PTs completely eliminated runway crossings at DFW in the demonstration.

Controller and pilot communications for the most critical frequency were clearly reduced with the addition of PTs. On the LE1 frequency, significantly fewer transmissions were made (22% relative reduction) with fewer words spoken (27% relative reduction). This resulted in the controllers and pilots spending less time on frequency (24% relative reduction) when compared to BL runs. Words were also spoken slightly slower on average during PT runs. In addition to being operationally relevant, these results were also statistically significant for the LE1 frequency. Such findings were consistent with controller debrief comments; controllers felt that the volume of communications was significantly reduced and they used less verbiage because concerns about crossings and reliance on pilot readbacks were alleviated. Many of the positive data results were also apparent in the findings of the other frequencies but generally to a lesser degree.

4. Conclusion

Based on the results of the data collected from the demonstration, it is clear that the stated objectives of the exercise have been met successfully. The controllers and pilots were afforded the opportunity to observe and experience the proposed airport improvements with realism and high fidelity. Despite the fact that this exercise was a demonstration, a considerable amount of data was available for analysis and presented in this report. The results revealed many interesting distinctions between the BL and PT conditions. However, because it was a demonstration, it is imperative to recognize that all results should be used and interpreted with due caution.

In conclusion, all controller and pilot participants agreed the demonstration was a good representation of operations at DFW and the proposed new taxiways; they perceived a marked improvement from BL to PT conditions; they all felt that the addition of PTs improved efficiency and reduced potential for runway incursions as demonstrated; and nearly all of the objective data showed that PTs would be advantageous to operations.

5. Experiment Working Group Observations

Members of the EWG were present throughout the demonstration. This section serves to capture their observances and interpretations of the events.

The EWG witnessed significant differences between BL and PT departure operations. To allow for comparisons, all traffic scenarios for the BL and PT conditions included approximately the same number of aircraft (a 20 to 30% increase over current operations). BL runs consistently resulted in the build up of substantial departure queues at the runway. These queues were large enough to impact the North bridge system accesses resulting in numerous aircraft still waiting to depart at the end of BL runs. Conversely, departure operations with the PTs produced very noticeable improvements. There were significant reductions in the queuing of aircraft at the end of the runway. During the PT runs, the controllers routinely had all aircraft out of the problem (i.e., departed) up to 5 to 7 minutes earlier than BL runs. Though a separate issue outside the scope of this demonstration, PT runs demonstrated that it may no longer seem necessary to require aircraft with tail heights of 47 feet or greater to exit the runway away from the departure runway. Departing aircraft were observed to be clear and well above the taxiing aircraft on the PTs.

Arrival operations also appeared to be favorably impacted by PT utilization. BL arrival operations demonstrated similar 'start/stop' patterns to those experienced in the field. This activity was created by the requirement to cross runways, resulting in choppy operations and delays. However, PT arrival operations showed a significant reduction in start/stop actions for the aircraft, allowing for more smooth and steady aircraft surface movement.

The tower cab environment appeared to change between the BL and PT runs. During the BL runs, the tower cab reflected the typically noisy and hectic activities of the controllers as they attended to the operations of the airport. The PT environment appeared to result in a calmer and less chaotic experience for controllers. There seemed to be a reduction of the noise level in the cab, less coordination between positions, less movement by the controllers to view the airport, and less tension and stress experienced by the controllers.

Reduced frequency congestion during PT runs also seemed to contribute to enhanced service by the controllers. The reduction in frequency activity allowed for additional services to be provided more frequently, for example, communicating departure sequences or weather restrictions to pilots awaiting departure.

Even though the controllers had limited exposure to PTs, the EWG felt that the taxi flows became more predictable and consistent, and that the execution of procedures progressively improved throughout the 4 days of the demonstration. They believe it is reasonable to expect continued improvements in the operation as exposure and familiarity is increased and repetition occurs. Because departure queues were depleted much more rapidly with PTs during the demonstration, the EWG also speculated that more opportunities could potentially be created to utilize the inboard runway for arrival aircraft in actual operations. Finally, after observing the South flow PT demonstration, greater PT benefits could be foreseen by the EWG. The Northeast Perimeter Taxiway could potentially provide even greater taxi flow and departure capacity gains during North flow conditions because there are currently three arrival flows that must cross Runway 35L that would experience benefit.

After the demonstration was complete, DFW representatives subjectively compared results from the DAPT Demonstration to earlier findings of fast-time simulation efforts. The out-to-off and on-to-in (oooi) times from fast-time simulations were very similar to the statistics of the inbound/outbound taxi times in this report. This exercise was purposely designed to be a demonstration, and consequently had limited statistical rigor and data fidelity, therefore, the findings of this report are best used for example and discussion purposes. However, the consistency in comparisons to the other research suggests that the demonstration data show some external validity and reliability.

Based on the observations and results of the demonstration, the EWG believes that the stated objectives of the DAPT Demonstration were successfully met. The controllers and pilots were afforded the opportunity to observe and experience the proposed airport improvements with realism and high fidelity, and a considerable amount of valuable data was available for analysis and presented in this report. In conclusion, the EWG believes that the proposed PT system for DFW provides for enhanced airport operations and a safer, more efficient environment.

Acronyms

ALPA	Airline Pilots Associations
APA	Allied Pilots Association
ASDE	Airport Surface Detection Equipment
B744	Boeing 747-400
BL	Baseline
CCE1	Cab Coordinator East 1
CVSRF	Crew Vehicle Systems Research Facility
DAPT	Dallas/Fort Worth International Airport Perimeter Taxiway
D-BRITE	Digital Bright Radar Indicator Tower Equipment
DFW	Dallas/Fort Worth International Airport
EWG	Experiment Working Group
FAA	Federal Aviation Administration
FFC	FutureFlight Central
GE1	Ground East 1
GE2	Ground East 2
GE3	Ground East 3
HITL	human-in-the-loop
ICAO	International Civil Aviation Organization
LE1	Local East 1
LE2	Local East 2
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NASA ARC	National Aeronautics and Space Administration Ames Research Center
NATCA	National Air Traffic Controllers Association
PAPI	Precision Approach Path Indicator
PT	Perimeter Taxiway
TCAS	Traffic Alert and Collision Avoidance System