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Precision Departure Release Capability (PDRC) Final Report

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Abstract

After takeoff, aircraft must merge into en route (Center) airspace traffic flows that may be subject to constraints that create localized demand/capacity imbalances. When demand exceeds capacity, Traffic Management Coordinators (TMCs) and Frontline Managers (FLMs) often use tactical departure scheduling to manage the flow of departures into the constrained Center traffic flow. Tactical departure scheduling usually involves a Call for Release (CFR) procedure wherein the Tower must call the Center to coordinate a release time prior to allowing the flight to depart. In present-day operations release times are computed by the Center Traffic Management Advisor (TMA) decision support tool, based upon manual estimates of aircraft ready time verbally communicated from the Tower to the Center. The TMA-computed release time is verbally communicated from the Center back to the Tower where it is relayed to the Local controller as a release window that is typically three minutes wide. The Local controller will manage the departure to meet the coordinated release time window. Manual ready time prediction and verbal release time coordination are labor intensive and prone to inaccuracy. Also, use of release time windows adds uncertainty to the tactical departure process. Analysis of more than one million flights from January 2011 indicates that a significant number of tactically scheduled aircraft missed their en route slot due to ready time prediction uncertainty. Uncertainty in ready time estimates may result in missed opportunities to merge into constrained en route flows and lead to lost throughput. Next Generation Air Transportation System plans call for development of Tower automation systems capable of computing surface trajectory-based ready time estimates. NASA has developed the Precision Departure Release Capability (PDRC) concept that improves tactical departure scheduling by automatically communicating surface trajectory-based ready time predictions and departure runway assignments to the Center scheduling tool. The PDRC concept also incorporates earlier NASA and FAA research into automation-assisted CFR coordination. The PDRC concept reduces uncertainty by automatically communicating coordinated release times with seconds-level precision enabling TMCs and FLMs to work with target times rather than windows. NASA has developed a PDRC prototype system that integrates the Center's TMA system with a research prototype Tower decision support tool. A two-phase field evaluation was conducted at NASA's North Texas Research Station in Dallas/Fort Worth. The field evaluation validated the PDRC concept and demonstrated reduced release time uncertainty while being used for tactical departure scheduling of more than 230 operational flights over 29 weeks of operations. This paper presents research results from the PDRC research activity. Companion papers present the Concept of Operations and a Technology Description.

1 Introduction

Future air traffic demands are expected to require a greater degree of integration among the automation systems used to manage arrival, departure and surface traffic. The next generation air transportation system (NextGen) envisions Integrated Arrival/Departure/Surface (IADS) operations as described in the Joint Planning and Development Office (JPDO) Integrated Work Plan [38] and in the FAA's NextGen Mid-Term Concept of Operations [35]. Various NextGen concepts [28, 31, 32] describe IADS operations that feature a greater degree of automated coordination as traffic flows from one control domain to the next in the tactical air traffic control environment.

A logical step towards the NextGen vision of fully-integrated arrival/departure/surface operations is to automate tactical scheduling of departure traffic that will join a constrained en route traffic flow. A commonly used tactical Traffic Management Initiative (TMI) is the Call For Release (CFR) procedure, which is also known as the Approval Request (APREQ) procedure. CFR procedures vary from facility to facility; however, they generally require the Air Traffic Control Tower (i.e., Tower) to request approval from the Air Route Traffic Control Center (i.e., Center) prior to releasing departures destined to specified airports. Earlier research [20, 21] at NASA Ames focused on automating inter-facility coordination during CFR procedures. An FAA-led effort built on this work to develop and evaluate the Departure Flow Management prototype [13].

Presently, en route tactical departure scheduling to meet CFR restrictions is often accomplished with the TMA decision support tool. Tactical departure scheduling with TMA is thoroughly described in Section 3 of the PDRC ConOps [1]. The PDRC concept combines the automated coordination demonstrated in the previous research [13,20,21] with the use of surface trajectory-based takeoff (OFF) time predictions and departure runway assignments to improve en route tactical departure scheduling with TMA during CFR procedures.

The PDRC research activity is an element of the Systems Analysis Integration and Evaluation (SAIE) Project of NASA's Airspace Systems Program. The Aviation Systems Division at NASA Ames Research Center is conducting the PDRC research activity based out of NTX. This research activity is also being accomplished using NASA Research Announcement contract (NNA11AC17C), which was awarded on 23 Sep 2011. Mosaic ATM, Inc. is the prime contractor for this work and CSC and Veracity Engineering are subcontractors. This document is a joint effort between NASA and contractor personnel.

NASA and the FAA are coordinating NextGen technology transfer via Research Transition Teams (RTTs). The RTTs have defined Research Transition Products (RTPs), consisting of distinct concept and/or technology elements that can be transferred as a package. PDRC is one of four RTPs currently being coordinated by the IADS RTT. NASA delivered an initial PDRC RTP package to the FAA in July 2012. Formal delivery of the core PDRC RTP package is slated for the summer of 2013. This final report will be one element of the PDRC RTP package. The FAA has identified the Time Based Flow Management (TBFM) Program and the Terminal Flight Data Manager (TFDM) Program as recipients of the PDRC RTP.

The research presented in this paper was conducted at NASA's North Texas Research Station (NTX) and associated FAA air traffic control facilities in the Dallas/Fort Worth area. Consequently, the examples and discussions in this paper primarily focus on the north Texas air traffic environment. Every effort has been made to ensure that the research results are applicable throughout the National Airspace System.

This final report provides an overview of the research activity and presents field evaluation results. Companion documents describe the concept of operations [1] and the technology development [2]. Effectively, these three documents comprise a three-volume report and the reader is urged to have all three papers at hand. Section 2 of this report provides an overview of present-day tactical departure scheduling operations and summarizes an analysis of shortfalls conducted at the outset of the PDRC research activity. Section 3 provides an overview of the

PDRC concept and shows how PDRC technology may be applied to existing tactical departure scheduling operations. Section 4 surveys the technology developed under this research activity. Section 5 describes the setup used for the PDRC field evaluations. Section 6 presents field evaluation observations and findings. Section 7 provides a preview of PDRC follow-on research. Finally, concluding remarks are offered in Section 8.

2 Tactical departure scheduling characteristics and shortfalls

This section presents an overview of present-day tactical departure scheduling operations and summarizes results of a shortfalls analysis. This material was originally published in two 2011 AIAA conference papers [4, 5] and is discussed in much greater detail in the PDRC Concept of Operations [1].

2.1 Tactical departure scheduling

Tactical departure scheduling is a process used by TMCs and FLMs to regulate air traffic flow to eliminate local demand/capacity imbalances and adhere to local traffic management initiatives (TMIs). Tactical departure scheduling is not required during normal NAS operations, as the airspace into which a flight is being released generally has sufficient capacity to accommodate the departure. However, during periods of high demand or low capacity for the airspace being scheduled into, tactical departure scheduling may be utilized.

Tactical and strategic departure scheduling processes are distinct from one another and are currently not directly integrated. Tactical departure scheduling is distinguished from strategic departure scheduling based upon scope (both temporal and geographic), precision requirements, and the decision support tools used. Strategic departure scheduling primarily uses the Traffic Flow Management (TFM) tool suite, while tactical departure scheduling is typically accomplished with the TMA decision support tool. Please consult References 1 and 5 for a more complete discussion of the differences between tactical and strategic departure scheduling.

It has been helpful to categorize tactical departure scheduling operations as either ***inbound*** or ***outbound*** depending on the TMA function used for scheduling. These scenarios are thoroughly discussed in Section 3.3 of the PDRC ConOps [1]. A brief overview will be provided here.

Figure 2:1 illustrates both scenarios for traffic in Fort Worth Center (ZFW). The blue arrows show various traffic streams ***inbound*** to Houston's George Bush Intercontinental Airport (IAH). These streams pass through ZFW airspace and converge at the TORNN meter arc. The green arrows depict a cross-country, overhead traffic stream ***outbound*** to Atlanta's Hartsfield-Jackson International Airport (ATL). DFW departures (broad gold arrows) seeking to join these streams must be merged with the en route traffic at meter points shown in red near the ZFW boundary.

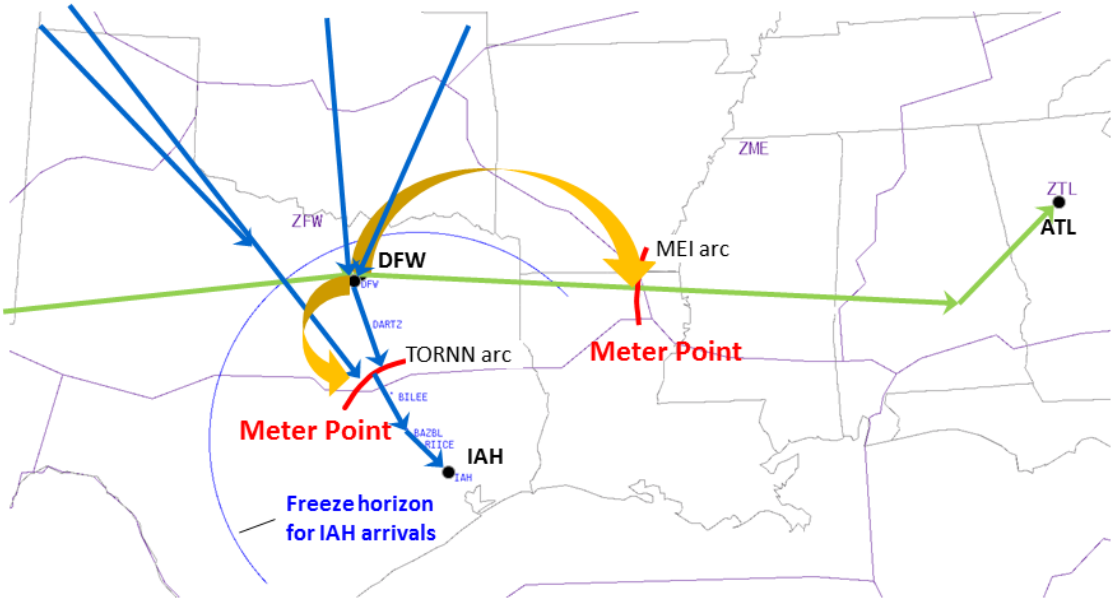


Figure 2:1 – Illustration of simultaneous inbound and outbound tactical departures from DFW International Airport.

The IAH stream is categorized as ***inbound*** because tactical departure scheduling is performed with the arrival-focused "internal departure" scheduling functions in the TMA system performing metering for IAH arrivals. This TMA system is "owned" by Houston Center (ZHU), although ZFW controllers perform some of the metering and ZFW TMCs can interact with the system. The ATL stream shown in Figure 2:1 is categorized as ***outbound*** because tactical departure scheduling is performed with the En Route Departure Capability (EDC) functions in the ZFW TMA system.

In either scenario, ZFW TMCs use TMA tactical departure scheduling functions to compute CFR times for DFW departures seeking to join the constrained en route streams. The scheduling process and coordination between ZFW TMCs and DFW Tower personnel is described in Section 3.3 of the PDRC ConOps [1].

2.2 Present-day system characteristics and shortfalls

The PDRC research activity characterized present-day tactical departure scheduling operations and identified shortfalls in the current system. This analysis is detailed in Reference 5 and the results are summarized in this section.

Reference 5 examines operational TMA and EDC data from all NAS facilities where the tools were deployed. The data included 1,082,000 flights operating during January 2011. The analysis indicates that these TMA and EDC tactical departure scheduling capabilities are widely used in the NAS today with over 65,000 scheduled aircraft per month using these methods. Increased utilization of tactical departure scheduling decision support tools has been fueled by expansion of adjacent center metering and nation-wide deployment of the EDC capability.

The PDRC ConOps [1] summarizes this analysis in a Venn diagram that has been excerpted in Appendix A (Figure 9:1) for easy reference. This diagram highlights the finding that tactical departure scheduling is used 3.5 times more often than strategic departure scheduling. The Venn diagram also shows that the ***inbound*** scenario described above occurs 5 times more often than the ***outbound*** scenario.

Although tactical departure scheduling with TMA and EDC has become a widely used component in NAS operations today and represents a significant improvement over the previous process, which lacked trajectory-based ascent modeling, analysis of the current system performance indicates that significant room for improvement exists by reducing departure time uncertainty. Based upon operational data analysis described in Reference 5, 6,792 inbound tactically scheduled aircraft and 1,911 outbound tactically scheduled aircraft in January 2011 NAS-wide are estimated to have missed the airspace slot they were scheduled into, due to departure time prediction uncertainty. Missed scheduled departure slots often lead directly to lost NAS capacity, most notably in the case in which an aircraft is scheduled frozen into an arrival TMA slot but does not meet its expected departure time window. Reference 5 proposes metrics measuring missed overhead stream slots; however, measuring the impact to the NAS of a missed departure slot is not always straightforward as some ability to recover the airspace resources exists, often at the cost of additional TMC or controller workload and/or inefficient flight paths.

Before concluding this discussion of present-day operations, note one highlight of an additional finding from Reference 5. The aforementioned Venn diagram (Figure 9:1) notes that “1 in 4 arrival metered flights is a tactical departure.” Stated another way, this means that 25% of ***inbound*** flights metered by an arrival TMA system are scheduled (i.e., have slots reserved) in the overhead stream *while they are still on the surface at the origination airport.* The 25% figure is a NAS-wide average. For some facilities nearly half of their TMA metered arrivals are scheduled as tactical departures. This is primarily due to the fact that TMA’s adjacent center metering capability has greatly extended the scheduling time horizon.

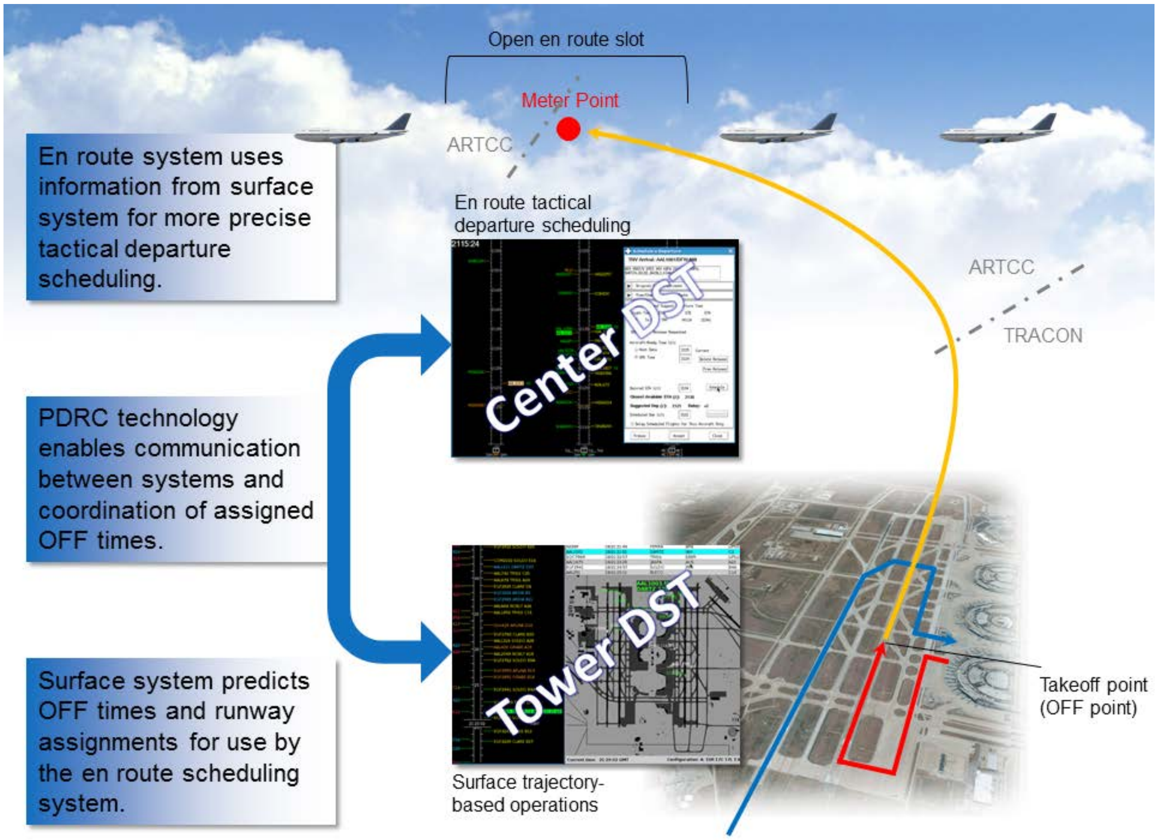
TMA development is continuing under the FAA’s Time Based Flow Management (TBFM) program. The TBFM program office is introducing new concepts designed at further extending the range of arrival metering. This increased range will be achieved through use of new concepts such as ‘Coupled Scheduling’ [25] and ‘Extended Metering.’ TBFM estimates of the maximum nominal metering range of an ‘Extended Metering’ system are approximately 725 nmi. As has been demonstrated with TBFM’s adjacent center metering systems, when the metering geometry expands, more airports enter the metering system from the airport surface (i.e., tactical departure scheduling). Due to the emerging demand for tactical departure scheduling and the significant uncertainty these flights represent to the en route schedule, the future need for integrating surface information into departure scheduling is expected to increase as well.

3 Concept and research prototype overview

NASA has developed the PDRC concept to address the shortfalls in present-day tactical departure scheduling operations. This section provides an overview of the PDRC concept and shows how PDRC technology may be applied to existing tactical departure scheduling operations. The companion ConOps document [1] provides additional details on this concept.

3.1 Concept overview

Figure 3:1 provides a high-level overview of the PDRC operational concept. This figure is applicable to both the outbound and inbound tactical departure scheduling situations described above. The right side of the figure depicts departure traffic operating under the CFR procedure where departures must be merged into constrained en route traffic flows. The left side of the figure shows the PDRC decision support tools used for tactical departure scheduling.



En route system uses information from surface system for more precise tactical departure scheduling.

PDRC technology enables communication between systems and coordination of assigned OFF times.

Surface system predicts OFF times and runway assignments for use by the en route scheduling system.

Figure 3:1 – Precision Departure Release Capability (PDRC) system overview.

The upper portion of the figure depicts a traffic stream in the en route domain that is under a CFR constraint. PDRC builds on an existing tactical departure scheduling decision support tool used by the Center to schedule departures into this constrained overhead stream. Ascent modeling in the en route decision support tool enables precise time-based scheduling and de-confliction at the meter point. The modeled ascent trajectory is illustrated by the gold line in Figure 3:1.

The lower portion of Figure 3:1 depicts the Tower environment where a NextGen surface trajectory-based decision support tool is in use. NextGen surface trajectory-based operations are enabled by a surface surveillance system and air carrier data sharing that provides intent and status information (e.g., gate assignments, estimated and actual pushback times). The surface trajectories computed and used by this decision support tool are represented by the blue and red lines in this figure.

PDRC focuses on the automated communication and use of surface trajectory-based OFF time predictions and runway assignments for tactical departure scheduling in CFR situations. In present-day operations, OFF time prediction and communication is manual. Automated PDRC communication is illustrated by the double-headed arrow on the left side of Figure 3:1. The Center decision support tool uses surface trajectory-based OFF time predictions for departure scheduling and coordinates release times with the Tower surface trajectory-based decision support tool. The Tower tool predicts OFF times and runway assignments for use by the Center tool in tactical departure scheduling and coordinates release times with the Center decision tool.

The focal point for PDRC is the OFF event in Figure 3:1 where the red trajectory joins with the gold trajectory on the departure runway. The Tower decision support tool computes surface trajectories to this point to develop OFF time estimates. The Center decision support tool computes airborne trajectories from the surface specified runway to the merge point in the overhead stream for tactical departure scheduling.

3.2 PDRC research prototype implementation overview

As discussed above, the PDRC concept calls for integrating the Center's tactical departure scheduling system with a surface decision support tool capable of providing trajectory-based OFF time predictions and departure runway assignments. Figure 3:2 illustrates the PDRC concept applied to present-day tactical departure scheduling operations.

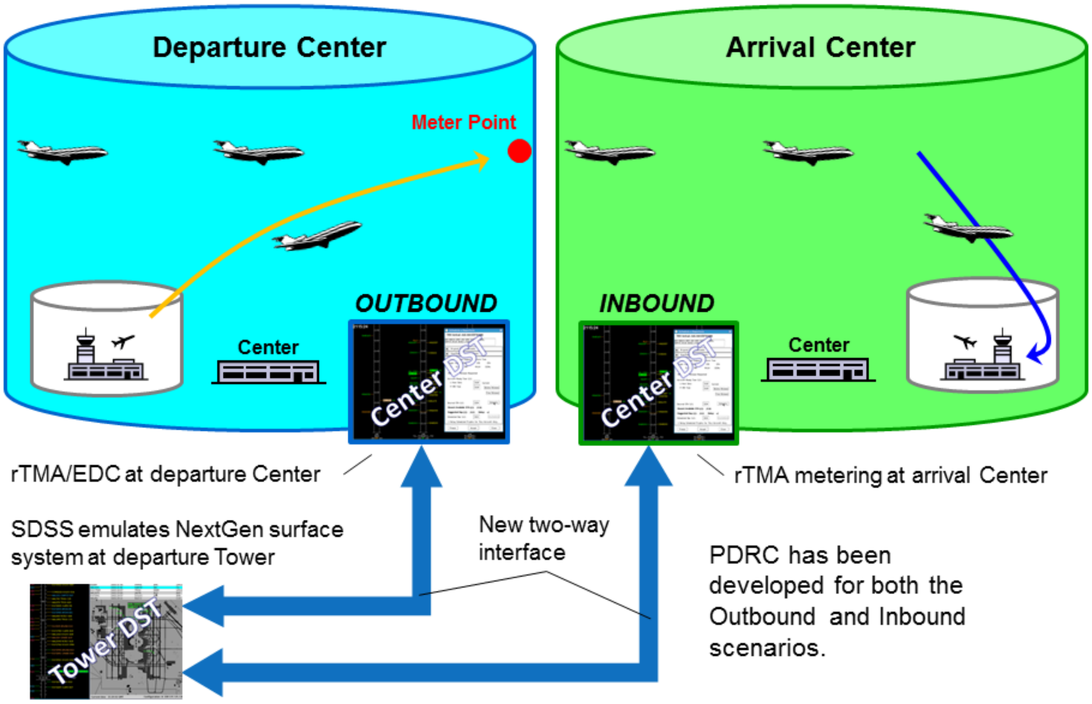


Figure 3:2 – PDRC prototype applied to present-day tactical departure scheduling operations.

The PDRC prototype uses a Research TMA (rTMA) system derived from operational FAA TMA software for Center tactical departure scheduling. The Surface Decision Support System (SDSS) serves as a surrogate for a NextGen trajectory-based surface management system. These and other elements of the PDRC prototype are described in Section 4 and in the companion Technology Description document [2].

The upper portion of Figure 3:2 illustrates present-day tactical departure scheduling operations for both the ***inbound*** and ***outbound*** scenarios described in Section 2.1. The tactical departure trajectory is shown in gold and merges with the constrained overhead flow at a meter point shown in red. The departure airport is on the left located inside the departure Center shown in blue. The arrival airport is on the right located inside the arrival Center shown in green.

The constrained overhead stream is shown flowing from left to right from the blue Center to the green Center where the stream becomes an arrival flow to the airport on the right side of the figure. Two separate TMA systems are depicted by the timeline user interface icons with "Center DST" labels. The TMA icons have a color-coded borders to depict which Center "owns" which TMA system.

Consider first the ***outbound*** tactical departure scenario. In this case traffic managers at the blue Center would use the blue TMA/EDC system to schedule CFR departures from the airport on the left into the constrained overhead stream. The traffic managers are using their own TMA/EDC system to schedule traffic outbound from their own Center. In this case, the constrained overhead flow happens to be an arrival stream for an airport in the adjacent Center, but it is treated like any other ***outbound*** flow for scheduling purposes.

Now consider the ***inbound*** tactical departure scenario. In this case, the departure from the airport on the left (in the blue Center) is scheduled into the green TMA system, which is being used by the green Center to meter the arrival stream to the airport on the right. The CFR call and tactical departure scheduling action is most likely being performed by traffic managers in the blue Center using an interface to the green Center TMA system. Thus, the blue Center traffic managers are using the green Center TMA system to schedule traffic ***inbound*** to the airport on the right.

The lower portion of Figure 3:2 shows PDRC applied to tactical departure scheduling operations. PDRC's double-headed arrows connect a trajectory-based surface system at the departure airport to ***inbound*** and ***outbound*** TMA systems. The PDRC concept and technology have been developed for both the ***inbound*** and ***outbound*** tactical departure scheduling scenarios.

In Section 2.2 it was noted that FAA TBFM program Adjacent Center Metering developments have significantly extended the reach of TMA arrival metering. Future TBFM developments in the areas of Coupled Scheduling and Extended Metering are expected to further extend the TMA arrival metering scheduling horizon. One can visualize this in terms of Figure 3:2 by imagining a much longer double-headed arrow connected to the green arrival metering TMA system thereby extending the reach of tactical departure scheduling.

4 Technology development

This section presents a survey of PDRC prototype technology development to highlight some of the more important accomplishments. Complete details regarding the PDRC prototype software are provided in the Technology Description companion document [2].

4.1 Overview

As described in Section 3, the PDRC concept integrates an en route tactical departure scheduling decision support tool (DST) with a NextGen surface trajectory-based DST. OFF time predictions and departure runway predictions from the surface tool are provided to the en route tool to improve departure scheduling calculations. The concept also facilitates coordination between Center and Tower TMCs/FLMs via the digital interface between the DSTs.

Design decisions for the PDRC prototype were driven by two primary considerations: (1) minimize technology transfer barriers, and (2) maximize the likelihood that FAA TMCs/FLMs would be willing to use the prototype during operational field evaluations. Both of these considerations weighed heavily in the decision to develop a research version of FAA TMA (i.e., rTMA) rather than use NASA's in-house TMA prototype (i.e., the Center TRACON Automation System or CTAS). The extra effort required to develop rTMA has paid dividends many times over both in technology transfer coordination and in TMC/FLM acceptance of the PDRC prototype. Use of rTMA also reduced the training required and enabled the team to take advantage of unexpected field evaluation opportunities involving unusual traffic configurations that likely would not have been adapted in a CTAS-based PDRC prototype.

The decision to use SDSS for the Tower tool was made for similar reasons. Although SDSS is not operationally deployed, it is used for research and development by various FAA organizations. This provides a common frame of reference for technology transfer coordination. Additionally, SDSS has benefitted from many years of NASA/FAA joint development, which has produced features and overall system robustness that helped the PDRC prototype system win acceptance with Tower TMCs/FLMs.

Figure 4:1 depicts a survey of PDRC technology development. This is a marked-up version of Figure 3:4 from the PDRC Technology Description [2]. A clean copy of this figure is provided in Appendix A (Figure 9:2) for easy reference. These figures are organized into three main sections according to the software systems being depicted. The left side of the diagram (in green) shows processes associated with SDSS. The right side of the diagram (in blue) shows software processes associated with rTMA. There are actually two rTMA systems shown on the right side of the diagram. The upper right portion of the diagram shows the rTMA system used for the ***outbound*** tactical departure scheduling scenario. This rTMA was configured as ZFW TMA/EDC. The lower right portion of the diagram shows the rTMA system used for the ***inbound*** tactical departure scheduling scenario. This rTMA was configured as ZHU arrival metering TMA.

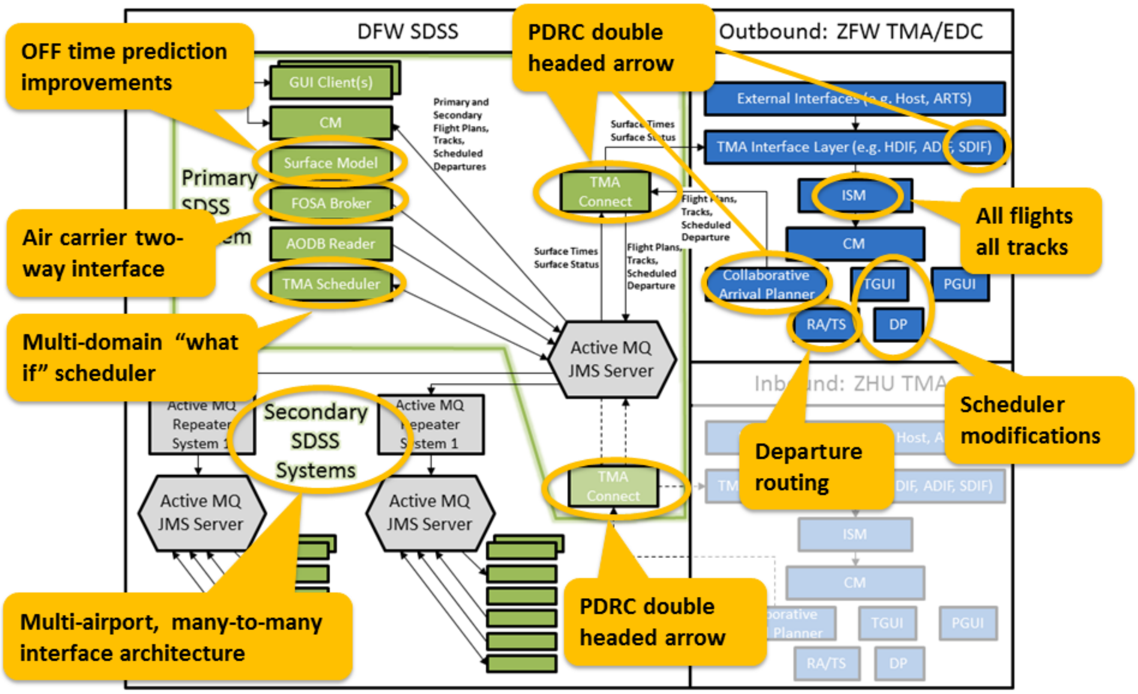


Figure 4:1 – PDRC prototype software architecture diagram marked up for technology development survey discussion.

4.2 Double-headed arrow

The signature piece of PDRC technology is the "double-headed arrow" of Figure 3:1 that represents two-way communications between the surface and en route components of the system. Two callout boxes in Figure 4:1 are labeled "double-headed arrow" and point to the software processes that enabled this new, two-way communications interface. On the SDSS (left/green) side a new TMA Connect process was created to handle all communications with TMA. On the rTMA (right/blue) side a new surface data interface (SDIF) process was created to receive data from SDSS. TMA's existing Collaborative Arrival Planner (CAP) data-sharing interface was extended to send data to SDSS.

4.3 All flights all tracks

Early in the PDRC prototype development process it was determined that it would be necessary for the en route and surface components to operate from a single, authoritative set of flight plan and airborne surveillance track data. The simplest solution was to have rTMA provide airborne flight plan and surveillance data to SDSS via the existing CAP interface. However, unlike NASA's CTAS prototype system, flight plan and track data is compartmentalized in the FAA's TMA system. The "all flights all tracks" callout on the rTMA (right/blue) side of Figure 4:1 denotes changes that were made to the rTMA input source manager (ISM) process to enable the full set of airborne flight plan and surveillance data to be delivered to SDSS.

4.4 Scheduler modifications

PDRC leverages existing TMA departure scheduling functionality. SDSS-computed Predicted Coordinated Off Time (PCOT) and Undelayed Coordinated Off Time (UCOT) values are delivered to rTMA via the double-headed arrow interface for use in scheduling by the dynamic planner (DP) and meter point dynamic planner (MPDP) processes. Both the UCOT and PCOT times were necessary so that rTMA could give credit to flights that encountered surface delays. This reduces the chance that a flight might be double-penalized by both a surface delay and a tactical departure delay. The "scheduler modifications" callout on the rTMA (right/blue) side of Figure 4:1 indicates that changes were required to the DP/MPDP and the departure scheduling user interface on the timeline graphical user interface (TGUI) process to enable automatic use of these SDSS-predicted OFF times.

4.5 Departure routing

The "departure routing" callout on the rTMA (right/blue) side of Figure 4:1 denotes improvements that were made to rTMA airborne departure routing within TRACON airspace. These improvements are particularly noteworthy because they were made possible by SDSS departure runway predictions communicated to rTMA via the PDRC double-headed arrow technology. The improvements were implemented via changes to the adaptation files used by rTMA's route analyzer (RA) and trajectory synthesizer (TS) processes. A description of these changes and the supporting analysis is provided in Appendix B (Section 10) of this paper. The Appendix B analysis shows TRACON flight time prediction errors have been reduced by up to a factor of 6 (i.e., average errors of 176 seconds reduced to 28 seconds) depending on the departure runway and departure fix combination. This analysis was conducted for the DFW North Flow configuration and a single southern departure fix (DARTZ) because this departure route was used frequently in the PDRC operational evaluations. However, the implemented solution provides TRACON flight time prediction improvements for all flows and departure fixes, and the error reduction will be comparable for flows and fixes with similar geometries.

4.6 OFF time prediction improvements

The "OFF time prediction improvements" callout on the SDSS (left/green) side of Figure 4:1 points to the SDSS Surface Model process and highlights numerous changes that have been implemented to improve SDSS OFF time predictions. Some of these changes were introduced when SDSS was up-leveled to version 9.x, which featured a redesigned Surface Model. The v9.x SDSS model includes additional instrumentation (e.g., the TrajectoryDashboard-1.0 tool) to support data collection and analysis.

Section II-E of the 2012 AIAA paper [6] identifies Aircraft Movement Area (AMA) taxi time predictions as a major contributor to OFF time prediction uncertainty. The paper recommends pursuing a more sophisticated model for AMA taxi operations. Appendix C (Section 11) of this paper describes the multivariate regression analysis that was conducted using outputs of the new TrajectoryDashboard tool mentioned above. Appendix C (Section 11) also addresses SDSS implementation details.

4.7 Air carrier two-way interface

The "air carrier two-way interface" callout on the SDSS (left/green) side of Figure 4:1 denotes the new two-way, Tactical Surface Data Exchange (TSDE) interface with American Airlines that was implemented to improve SDSS OUT time predictions and to capture actual OUT events for data analysis. This interface was developed in collaboration with the FAA's Surface Trajectory Based Operations (STBO) Project.

4.8 Multi-domain 'what if' scheduler

The "multi-domain 'what if' scheduler" callout on the SDSS (left/green) side of Figure 4:1 points to the completely new TMA Scheduler process that was developed specifically to support PDRC research. The SDSS TMA Scheduler process collects internal rTMA scheduling information and makes it available to Tower TMCs/FLMs for 'what-if' analyses and better visibility into the en route portion of the tactical departure scheduling problem. This multi-domain scheduler performs the specified hypothetical scheduling tasks (e.g., 'what if' scheduling) and presents the results to the user. This new process supports the enhanced scheduling capabilities research that is briefly discussed in Section 7.2 of this paper.

4.9 Multi-airport, many-to-many interface architecture

The "multi-airport, many-to-many interface architecture" callout on the SDSS (left/green) side of Figure 4:1 denotes a capability developed in PDRC that allows the surface system to connect to multiple en route systems for PDRC data exchange. The end state integration of PDRC capability in the NAS envisions many-to-many connections from/to surface and en route systems.

Planned PDRC follow-on research addresses more complex scheduling constraints (e.g., TRACON-level flow constraints) and lesser-equipped airports. The TRACON Departure Scheduling research activity, briefly discussed in Section 7.3 of this paper, will build on the multi-airport, many-to-many capabilities developed in PDRC.

This completes the survey of PDRC technology development. Please consult the Technology Description document [2] for a more detailed description of the technology associated with PDRC.

5 Field evaluation setup

Three PDRC field evaluations have been conducted at NASA's North Texas Research Station (NTX) field site. A live-data, operational environment shadow evaluation was conducted in July 2011 [4]. This was followed by two operational evaluations (Block 1 & 2) conducted in the summer of 2012 and the winter of 2012/2013. The Block 1 & 2 operational evaluations were essentially a single operational evaluation with a built-in pause to allow for interim data analysis and system enhancements. Since the evaluation setup was generally similar in all three cases it will be described here to avoid repetition in the analysis and results sections that follow.

5.1 Physical layout

Figure 5:1 depicts the physical layout for the PDRC field evaluations. In this figure, DFW airport runways are highlighted in yellow in the center of the figure. ZFW and the NTX laboratory are located about 3 miles southwest of the airport. PDRC installations are shown in the inset images.

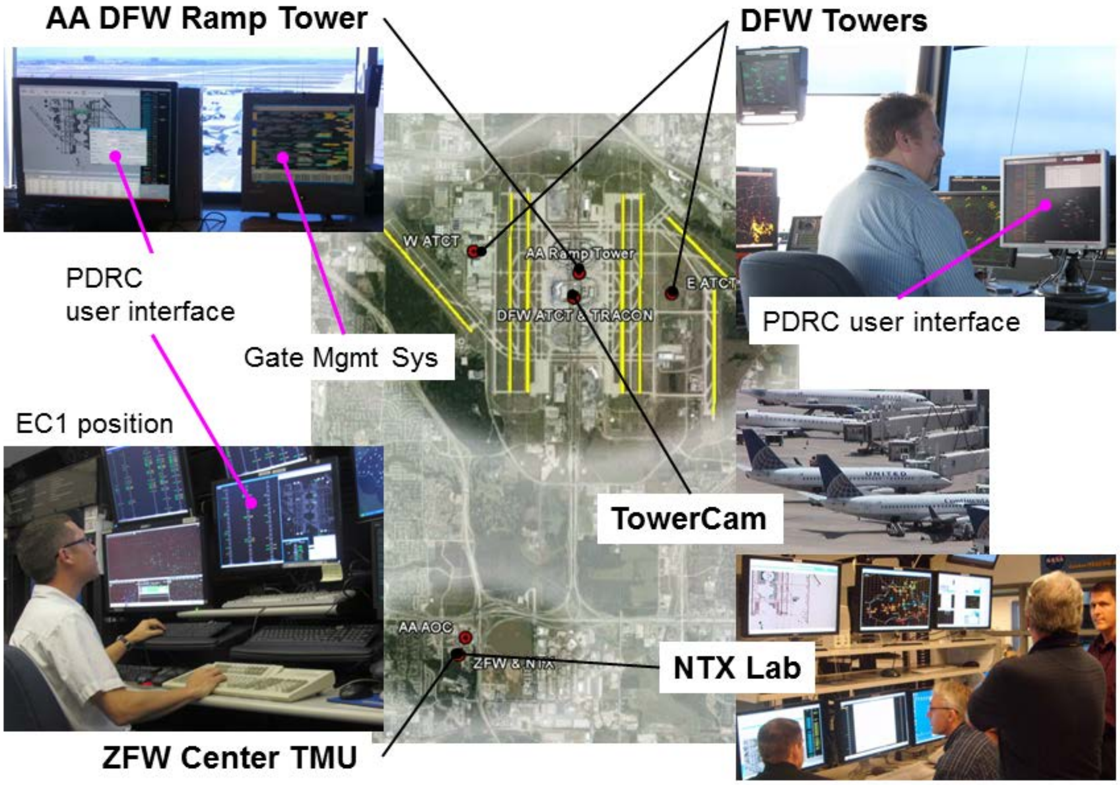


Figure 5:1 – PDRC field evaluation positions in the vicinity of DFW airport..

5.1.1 ZFW Center TMU

This location corresponds to the Center role in the PDRC operational scenario described in Section 6 of the PDRC Concept of Operations [1]. ZFW's PDRC user interface is installed in the Traffic Management En Route Coordinator (TMEC or EC1) position shown in the lower left portion of Figure 5:1. The PDRC user interface was located at the EC1 position during both operational evaluations. During the July 2011 shadow evaluation the PDRC user interface was installed in a non-operational position in the TMU.

As is typical for Centers, the ZFW TMU is physically separate from the specialties where sector controllers work. The TMU is staffed by TMCs and Supervisory TMCs (i.e., STMCs) and only these personnel interacted with the PDRC prototype system. NASA personnel provided PDRC prototype training for all ZFW TMCs and STMCs – approximately 30 individuals. Most of the TMU staff participated in both Block 1 & 2 operational evaluations.

5.1.2 DFW Towers

This location corresponds to the Tower role in the PDRC operational scenario described in Section 6 of the PDRC Concept of Operations [1]. PDRC user interfaces are installed at the TMC desks at both East and West Towers at DFW. The inset image in the upper right portion of Figure 5:1 shows the East Tower PDRC installation. The West Tower installation is similar.

The TMU functions in the Tower are much less segregated than they are in the Center. Consequently, all Tower personnel were involved in the PDRC field test, some directly and others indirectly. The direct involvement was managed by Tower TMCs who are part of the

Metroplex Traffic Management Unit that also contains STMCs and TMCs from DFW TRACON.

5.1.3 AA DFW Ramp Tower

The PDRC user interface at American Airlines' DFW Ramp Tower is shown in the top left corner of in of Figure 5:1. This position was established for the July 2011 shadow evaluation to gain a better understanding of the available air carrier data and to experiment with it through manual data entry into the PDRC system. In essence, the NASA observer at this position acted as a surrogate for the TSDE data interface mentioned in Section 4.7 and detailed in the companion Technology Description document [2]. American Airlines continues to provide valuable data and support for the PDRC research activity.

5.1.4 NTX Laboratory

The NTX Laboratory shown in the lower right corner of Figure 5:1 served as the command center for the Block 1 & 2 operational evaluations just as it did for the July 2011 shadow evaluation [4]. Due to the target-of-opportunity nature of the operational evaluations, services provided by the NTX lab had to be virtualized and automated to a greater extent than for the shadow evaluation to support the agile evaluation methodology described below.

5.2 Apparatus

The primary apparatus for the Block 1 & 2 operational evaluations was the PDRC prototype system itself. Complete details are provided in the companion Technology Description document [2] and can be summarized as follows:

- rTMA decision support tool including GUI clients (typically 3 per system)
- SDSS decision support tool including GUI clients (typically 4 per system)
- Live data feeds for rTMA and SDSS including Center, TRACON, and ASDE-X surveillance, Rapid Refresh forecast winds aloft, and air carrier data
- PDRC two-way interface connecting rTMA and SDSS

For the Block 1 & 2 operational evaluations, the PDRC prototype system was hosted on a dedicated Linux server configured with two 2.5 GHz quad-core CPUs and 48GB RAM. Each PDRC server ran all of the rTMA and SDSS computational processes hosted on one virtual machine (VM) with a second VM hosting the associated rTMA and SDSS GUI clients, and services for distributing the GUI clients to remote user displays.

The PDRC Block 1 & 2 operational evaluation depended upon a number of NTX-built research support systems. One of the most important is the NextGen Emulation System (NEXUS) desktop distribution system, which uses a graphical desktop sharing utility (i.e., Virtual Network Computing) to distribute all PDRC GUI clients to the various end-user display machines. The NEXUS desktop distribution system also provides for digital video recording of all displays for post-test review.

The PDRC research team also used the NTX-developed Terminal Area Radio Telecast System (TARTS) and TowerCam systems to support Block 1 & 2 operational evaluation data collection. TARTS provides streaming audio of controller/pilot radio transmissions received over-the-air at the NTX laboratory. TowerCam consists of remote control pan/tilt/zoom cameras mounted on DFW's central Tower.

5.3 Agile and opportunistic evaluation methodology

A key observation from the July 2011 shadow evaluation experience [4] was the need for an agile and opportunistic evaluation methodology for the operational tests that were to follow. Tactical departure scheduling situations are dependent on unpredictable weather and traffic volume factors making it necessary for the research team to adopt a target-of-opportunity mentality towards data collection. Since data collection “runs” could not be scheduled in advance, the team could not count on having research observers on position to collect data. Likewise, it was simply impractical to have a small, dedicated cadre of TMCs/FLMs to work with the research team as was done in past NASA operational evaluations. Even without considering cost, it was concluded that it would be logistically impossible to have the participation of research observers on position and a small cadre of TMCs/FLMs for the entire evaluation.

Consequently, the PDRC research team developed an agile and opportunistic data collection system to partially compensate for the target-of-opportunity evaluation challenges noted above. A key aspect of this system involved immediate notification via email and text message when a tactical departure scheduling opportunity arose. Upon receiving this notification, PDRC evaluation team members coordinated with each other via email and/or text message to identify who would monitor the system. The designated system monitor would be ready to offer assistance should the TMCs require technical support and the monitor ensured that research data was collected.

The PDRC prototype systems are, of course, fully instrumented. Every input and output and a wide array of internal parameters are recorded and archived. Additional instrumentation is provided by the NEXUS desktop distribution system (Section 5.2), which enables research observers to remotely monitor and analyze TMC/FLM interactions with PDRC. This “video replay” capability has proven to be immensely valuable for filling gaps when an observer was unable to monitor the CFR event live and for following up on TMC/FLM feedback.

The target-of-opportunity evaluation methodology is highly dependent on participant training. Since a dedicated cadre was not an option, the PDRC team trained more than 30 ZFW TMCs/STMCs on use of the PDRC prototype over the course of the research activity. This challenging task was made manageable thanks to the decision to use rTMA for the en route portion of PDRC. Since rTMA was derived directly from a recent version of FAA TMA, nearly all features and functions are the same. This allowed the trainers to focus just on PDRC-specific features. NASA was also fortunate to have several ZFW TMCs/STMCs assist with training their colleagues.

NASA personnel provided PDRC prototype training for all DFW TMCs and STMCs. DFW Tower participation in the July 2011 shadow evaluation and the Block 1 operational evaluation was limited to TMCs and STMCs. For the Block 2 operational evaluation, the DFW Tower FLMs were included in the group of evaluation participants. DFW TMCs conducted the training for the FLMs. DFW STMCs also developed briefings on PDRC operational evaluation procedures and delivered these to all DFW Tower controllers.

Gathering feedback from TMCs/FLMs as they used PDRC was a primary evaluation objective. This task was particularly challenging with no on-position observers and without the luxury of dedicated debriefing sessions with a controller cadre. The PDRC team compensated for these shortcomings by creating several avenues for TMC/FLM feedback:

- Electronic feedback forms accessible directly from PDRC user interfaces
- NTX technical support hotline
- Periodic “how goes it” meetings

TMC/FLM feedback will be examined more thoroughly in Section 6.4

5.4 Inbound scenario field evaluation challenges

Section 2.2 summarized research conducted in 2011 that examined shortfalls in present-day tactical departure scheduling operations. This research identified a large benefits pool for improved tactical departure scheduling and showed that the majority of the potential benefits are associated with the ***inbound*** scenario. Additionally, it is expected that FAA TBFM developments will continue increasing ***inbound*** usage at the expense of ***outbound*** usage. One can easily envision a future where the ***outbound*** scenario no longer exists. These factors made the ***inbound*** scenario an enticing target for PDRC field evaluations.

However, the very factors that make the ***inbound*** scenario more interesting also make it more difficult to evaluate. The ***inbound*** scenario involves TMA arrival metering, which operates in a closed-loop mode (i.e., meter times displayed on sector controllers’ radar scopes). In contrast, the ***outbound*** scenario utilizes the TMA/EDC function which, in current practice, operates in open-loop mode. TMCs in the TMU use TMA/EDC to provide the sector controllers with a workable traffic situation, but sector controllers are not required to meet TMA/EDC meter times.

The closed-loop operation of TMA arrival metering requires a two-way interface to the Center Host or ERAM computer so that meter times can be delivered to the sector controller scopes. Even though rTMA is derived directly from FAA TMA it is still a research system and has not been approved for two-way Host or ERAM interface. An additional complication is illustrated in Figure 3:2, which shows that the inbound scenario requires the rTMA portion of PDRC to be deployed at the arrival Center. Consequently, the field evaluation threshold is much higher for the ***inbound*** scenario with TMA arrival metering.

This threshold difference may cause one to question the value of evaluating only the ***outbound*** scenario, but there are two main reasons for doing so. First, as shown in Figure 3:2, the surface portion of the evaluation is virtually identical between the ***inbound*** and ***outbound*** cases. This is particularly true for the common case of DFW-to-IAH tactical departures scheduling, which sometimes operates ***inbound*** and sometimes ***outbound***. During the Block 1 field evaluation there were numerous occasions where the Tower TMCs attempted to use PDRC for an ***inbound*** IAH scenario because they didn’t have visibility into which scenario was in play – it all looked the same from the Tower side. Thus, all research on the surface component of PDRC applies equally to the ***outbound*** and ***inbound*** cases and the ***outbound*** scenario is satisfactory for evaluating any enhancements or extensions made on the surface side. Second, although there are distinct differences between the scenarios on the Center side, the TMC role is very similar between the two scenarios.

6 Field evaluation observations and findings

This section presents observations and findings, quantitative and qualitative, collected during the PDRC shadow and operational evaluations.

6.1 Evaluation overviews

The brief overviews for each of the PDRC evaluations provide the necessary background for the observations and findings presented in subsequent sections. The overviews document the number of tactical departures that were scheduled with the PDRC prototype. For a flight to count as a PDRC-scheduled flight, both the Tower and Center TMCs/FLMs had to schedule the flight using the PDRC system and the scheduling procedure described in Section 6.1 of Reference 1. A summary of the PDRC scheduling procedure is provided in Appendix A (Figure 9:3) for easy reference.

6.1.1 July 2011 shadow evaluation

Dates:	13 – 29 Jul 2011
Duration:	61 hours of on-position observations over 12 days
Participants:	ZFW and DFW TMCs/STMCs
Flight count:	5 operational departures scheduled in the ***outbound*** scenario

Objectives:

- PDRC prototype and test apparatus shakedown
- TMC training
- Live-traffic shadow evaluations with TMCs in their operational environment

The July 2011 shadow evaluation has been thoroughly documented in Reference 4, so only a brief summary will be given in this paper. As previously noted, this was primarily a training and shakedown evaluation session. NASA observers were stationed at operational positions at ZFW and the DFW East Tower to provide training and technical support and to record observations and feedback as TMCs operated the system in shadow mode. The NASA observer at American Airlines DFW ramp tower was tasked with transferring updated OUT estimates from AA systems to the PDRC prototype (in lieu of the not-yet-implemented TSDE interface) and recording observations from that unique perspective.

Notably, this was the only evaluation where PDRC was operated in the ***inbound*** scenario (see discussion in Section 5.4). TMCs provided feedback on PDRC performance (shadow mode only) in this scenario, and the evaluation team explored potential workarounds for inbound scenario operational evaluations. None proved satisfactory. On the final day of the evaluation the test shifted from shadow to operational mode wherein the PDRC prototype system was used to schedule five actual DFW departures using the ***outbound*** scenario.

6.1.2 Block 1 operational evaluation

Dates:	30 Apr 2012 – 26 Jul 2012
Duration:	**13 weeks** of continuous target-of-opportunity evaluations
Participants:	ZFW and DFW TMCs/STMCs
Flight count:	**120** operational departures scheduled in the ***outbound*** scenario

Objectives:

- Validate the PDRC concept
- Demonstrate PDRC prototype system performance
- Identify and quantify sources of uncertainty in the tactical departure scheduling process

Key changes since July 2011 shadow evaluation are summarized below. See the Technology Description document [2] for complete details.

- The PDRC surface component (i.e., SDSS) was upgraded to version 9.x, which features an improved trajectory-based airport surface model. The improved model provides better OFF time predictions and has additional instrumentation to support data collection and analysis.
- The PDRC en route component (i.e., rTMA) was re-derived from FAA TMA version 3.12. Also, rTMA now has the ability to use departure runway from SDSS to improve airborne route models.
- A new two-way TSDE interface with American Airlines was implemented to improve SDSS OUT time predictions and to capture actual OUT events for data analysis. This interface was developed in collaboration with the FAA's STBO Project and is discussed in Section 4.7.

Data from the Block 1 evaluation are collected in Appendix D (Section 12). Table 12:3 provides a count of PDRC-scheduled flights by date and destination airport. This table shows that the two Houston-area airports (IAH and HOU) accounted for about 78% of the flights scheduled with PDRC during the Block 1 evaluation.

Twenty-seven feedback forms were received during the Block 1 evaluation. These are discussed in Section 6.4. TMC feedback was also gathered at team "how goes it" meetings on May 14, May 31, and June 11. Clarity of communications during CFR coordination was a major topic of discussion at the initial Block 1 "how goes it" meetings. See Section 6.2 for a discussion of findings on this topic.

6.1.3 Block 2 operational evaluation

Dates: 5 Nov 2012 – 28 Feb 2013
Duration: **16** weeks of continuous target-of-opportunity evaluations (~150 hours of CFR)
Participants: ZFW TMCs/STMCs and DFW TMCs/STMCs/FLMs
Flight count: **118** operational departures scheduled in the ***outbound*** scenario
Objectives:

- Validate the PDRC concept
- Demonstrate PDRC prototype system performance
- Evaluate improvements to PDRC Core technology.

Key changes since the Block 1 evaluation are as follows:

- Merged with latest SDSS baseline (v9.2.x) to leverage FAA investments.
- New adaptation logic to improve taxi time predictions.
- Completely new SDSS software to enable Tower display of overhead stream slot information.
- User interface changes (e.g., colors, layout) to address TMC feedback.
- New "go/no go" status panel to improve TMC coordination.
- rTMA improvement to correct a scheduling anomaly.

Data from the Block 2 evaluation are collected in Appendix E (Section 13). Table 13:3 provides a count of PDRC-scheduled flights by date and destination airport. This table shows that the two Houston-area airports (IAH and HOU) still account for the majority of PDRC flights; however Denver (DEN) now ranks 2nd with 22 PDRC-scheduled flights while it had none in the Block 1 evaluation. The increase in CFR instances for DEN may be related to increased use of Optimized Profile Descent (OPD) arrival procedures at that airport. DFW traffic management experts report early indications that increased arrival stream compression apparently associated with OPDs is resulting in more frequent and extensive restrictions at airports with more OPD arrivals like DEN. It should also be noted that the Block 2 operational evaluation had about 83% more (24 vs. 14) west-side departures than the Block 1 evaluation and virtually all DEN flights would depart on the west side of DFW. More analysis is required to verify a correlation between DEN OPD arrival operations and DFW-to-DEN CFR frequency.

For the 16 week Block 2 evaluation, the PDRC prototype was estimated to have operated in CFR mode for approximately 150 hours. This estimate was made possible by the new CFR two-way status indication system (i.e., “thumbs up/down” indicator) described in Section 6.4 of Reference 2. Logging features built into the status indicator record when both facilities have selected a “thumbs up” status. The total “two thumbs up” time for Block 2 amounted to a little more than 150 hours over the 16 week evaluation period. Twenty-three feedback forms were received during the Block 2 evaluation, discussed in Section 6.4. TMC feedback was also gathered at team “how goes it” meetings on Dec 18 and Feb 14.

6.1.4 March 2013 shadow evaluation

Dates: 25 – 29 Mar 2013
Duration: 3 shadow evaluation and structured interview sessions
Participants: ZFW TMC, ZFW STMC and two DFW TMCs
Objectives: obtain early feedback on PDRC enhanced scheduling concepts.

Live traffic shadowing sessions and storyboard-driven structured interviews were used to obtain early feedback on PDRC enhanced scheduling concepts from a focus group of four ZFW and DFW subject-matter experts. See Section 7.2 for a discussion of this research thread.

6.2 Communication uncertainty

A key finding from the July 2011 PDRC shadow evaluation [4] was that there may be varying interpretations and practices regarding the actual target release time within the CFR compliance window. Consequently, the PDRC research team worked with ZFW and DFW TMCs to reduce this source of uncertainty for the operational evaluations. The diagram shown in Figure 6:1 was developed to facilitate communication between the researchers and TMCs regarding CFR time. This diagram was used during test preparation and training for the Block 1 operational evaluation.

The bottom portion of Figure 6:1 provides a pictorial representation of key events for a departing flight. The upper portion shows these same events mapped to a timeline similar to those displayed on the rTMA and SDSS decision support tools used for PDRC. The left side of the timeline shows these events from the human (i.e., TMC) perspective while the right side of the timeline shows them from the PDRC software system perspective. The discussion that follows will center on four events depicted in Figure 6:1. Considering the events chronologically, the first is “Cleared for T/O,” which is simply the time at which the Tower Local controller issues the takeoff clearance. At this point control over the actual departure time is ceded to the pilot. The next significant event is “Start of Roll,” which will occur at some variable interval after the takeoff clearance. The “Start of Roll” variability is due to a combination of human factors and aircraft characteristics. The next key event is “Wheels OFF,” which is the time at which an onboard weight-on-wheels switch would indicate that the aircraft is airborne. The interval between “Start of Roll” and “Wheels OFF” is almost entirely a function of aircraft takeoff weight and performance characteristics. The final event of interest is labeled “Tagged Up.” This corresponds to the time at which the departing flight is acquired by the TRACON surveillance radar and “tags up” on the radar scope. In communications with flight crews, Tower personnel often use “wheels in the well” (i.e., landing gear fully retracted) as a useful approximation for the “Tagged Up” event.

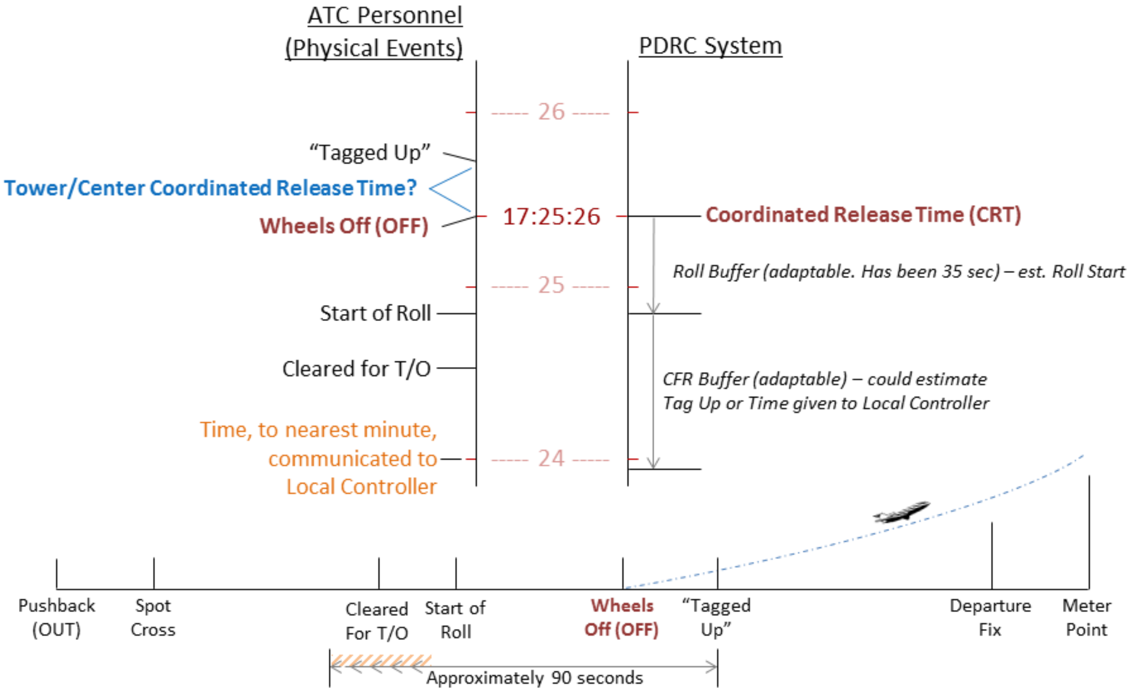


Figure 6:1 – Significant communication uncertainty exists in the manual communication of CFR times.

Uncertainty in CFR communications begins with varying interpretations and/or assumptions concerning the four key events described in the preceding paragraph and shown in Figure 6:1. Achieving higher precision in tactical departure scheduling requires that the Tower and Center TMCs/FLMs and their software tools all be on the same page when exchanging information about these events. The SDSS predicted surface trajectory (i.e., the red trajectory in Figure 3:1) ends at the runway threshold at the “Start of Roll” event. The rTMA software uses “Wheels OFF” as the starting point for airborne trajectory computations (i.e., the gold trajectory in Figure

3:1). PDRC software provides an adjustable “Roll Buffer” parameter to compensate for the difference between the “Start of Roll” and “Wheels OFF” events thereby connecting the red and gold trajectories of Figure 3:1.

On the human side of the Figure 6:1 timeline, Center TMCs primarily focus on the “Wheels OFF” event because this is the starting point of the airborne trajectory computed by their TMA tool. TMA requires an “aircraft ready time” to be entered via the departure scheduling user interface. This ready time is the predicted “Wheels OFF” time. Without PDRC, the “aircraft ready time” is manually estimated by the Tower TMC/FLM and verbally communicated to the Center TMC for entry into TMA/EDC. With PDRC, the “aircraft ready time” estimate is automatically set to the current SDSS OFF time prediction. See Section 6.2.4 of the ConOps [1] for a detailed description of this portion of the PDRC scheduling process.

Tower TMCs/FLMs simultaneously consider multiple events on the Figure 6:1 timeline during CFR operations. They must meet the release time coordinated with the Center TMC by communicating a target time (or window) to the Local controller that accounts for other departure and arrival traffic, takeoff clearance reaction time, and takeoff roll time. Remember that positive control of OFF time is ceded to the pilot at the “Cleared for T/O” event, so the Tower TMC/FLM and Local controller must account for all of the other factors when issuing the takeoff clearance.

Discussions with Tower TMCs led to an important finding that influenced the PDRC software design. Specifically, it was found that the Tower was aiming for “Tagged Up” instead of “Wheels OFF” in meeting the release times coordinated with the Center. Although the Center and Tower TMCs appear to have been operating with different definitions for Coordinated Release Times, the discrepancy was not large enough to impact Baseline CFR operations. Data collected during the Block 1 evaluation show the “Tagged Up” event is, on average, 25 seconds later than the observed “Wheels OFF” time. This 25-second difference only became significant with the push for higher precision during the PDRC operational evaluations. The PDRC software easily accommodates the different Coordinated Release Time definitions with the “CFR Buffer” parameter shown in the Figure 6:1. This buffer allowed the Center and Tower TMCs/FLMs to continue using their standard CFR procedures. Note that the value of the “CFR Buffer” parameter may be different from one facility to the next.

A more significant source of uncertainty involves the use of Coordinated Release Time windows and verbal communication of the start/stop times for those windows. In present-day (i.e., non-PDRC) CFR operations, the Coordinated Release Time is communicated verbally over facility inter-phone from the Center to the Tower. A recent FAA Notice [39] has amended the FAA 7110.65 standing order to establish standard compliance window dimensions. The Notice states “when CFR is in effect, release aircraft so they are airborne within a window that extends from 2 minutes prior and ends 1 minute after the assigned time, unless otherwise coordinated.” This standardized window is consistent with the -2/+1 window that was observed in use at ZFW and DFW during non-PDRC operations. The new order does not specify phraseology for communicating the time window.

Use of a Coordinated Release Time window automatically introduces release time uncertainty equivalent to the size of the window. However, observations and interviews with Center and Tower TMCs revealed even more uncertainty than expected associated with use of windows. To begin with, the –2/+1 window is often, in practice, a 3 minute 59 second window due to frequent inclusion of the termination minute in the window itself. Also, variations in the phraseology used to verbally communicate window start/stop times that contributed to CFR uncertainty were observed.

Table 6:1 provides a hypothetical example that is representative of actual observed variations. Note that the TMA/EDC Coordinated Release Times are displayed to Center TMCs at minutes-level granularity.

Table 6:1 – Phraseology and interpretations in communication of Coordinated Release Time windows.

Center receives a time from TMA/EDC	Times(s) communicated to Tower have various interpretations	
Coord. Release Time	First time	Second time(?)
17:25:26 TMA/EDC computes a time to seconds-level precision but display is limited to minutes-level precision: **1725**	1723	1726
	1723	“void at” 1726
	1725	1727
	1725	“void at” 1727
	1725	1726
	1725	“void at” 1726
	1725	None communicated

After receiving the time window verbally from the Center, the Tower TMC/FLM may apply different interpretations to the information. In some cases the TMC receiving the information may assume the beginning of the first minute to the end of the last minute given. In the case of the time communicated at 17:23 to 17:26, this interpretation would be 17:23:00 to 17:26:59, which would mean a 3:59 departure window.

PDRC reduces the ambiguity in CFR coordination communications via a digital interface (i.e., the PDRC double-headed arrow) between the Tower and Center decision support tools. Section 6.2.5 of the ConOps [1] describes how the Coordinated Release Time (a.k.a. Scheduled Departure Time in PDRC software terminology) is delivered from rTMA/EDC to SDSS where it is displayed at seconds-level precision. For the Table 6:1 example, PDRC presents the Tower TMC/FLM with an unambiguous Coordinated Release Time of 17:25:26 to use for CFR coordination with the Local controller. In the present-day environment (i.e., without Tower electronic flight strips) the Tower TMC/FLM will round the seconds-level precision PDRC time to the appropriate minute and communicate this target time to the Local controller per standard procedures.

6.3 Characterizing CFR scheduling operations at DFW

A significant event of interest for tactical departure scheduling is when (and where) the scheduling decision is being made. Previous observations have shown that the CFR scheduling decision is often made at or near the spot, but there is significant variability in the timing of this scheduling decision. Performance goals for the Block 1 & 2 operational evaluations were for PDRC-enabled tactical departure scheduling to conform to present-day standard operating procedures and meet or exceed the performance of manual tactical departure scheduling. In other words, TMCs were not asked to make the CFR scheduling decision any earlier than they would without PDRC.

Before a detailed discussion of the evaluation results, it will be helpful to characterize CFR scheduling operations for the Baseline, Block 1, and Block 2 data sets. DFW International Airport is distinguished by two operational Towers and a centrally-located terminal complex served by a north/south freeway (International Parkway) that bisects the airport property. Consequently, DFW is often characterized as two airports in very close proximity. The east-side "airport" has a control tower and four runways. The west-side airport has a control tower and three runways. The east and west sides are linked by four bridges (a pair to the north and a pair to the south) that carry taxiways over International Parkway.

DFW primarily operates in either south flow or north flow runway configuration. Thus, it is helpful to sort DFW CFR scheduling operations into four categories: east side vs. west side and south flow vs. north flow. Table 6:2 shows the distribution of Baseline, Block 1, and Block 2 departures amongst these four categories. Note that the data presented in this section correspond to the sets used for the OFF time compliance comparisons of Section 6.5.

Table 6:2 – DFW CFR scheduling operations by side and flow.

DFW category	Baseline		Block 1		Block 2	
	count	%	count	%	count	%
east side / south flow	170	49.7	71	68.9	36	35.0
east side / north flow	60	17.5	18	17.5	35	34.0
west side / south flow	84	24.6	12	11.7	15	14.6
west side / north flow	28	8.2	2	1.9	9	8.7
total	342		103		95	

Figure 6:2 plots the 342 Baseline departures on a surface map of DFW. The symbol positions represent the point at which the Center scheduled the departure with TMA/EDC. Circles represent flights departing the east side and triangles show west-side departures. South flow is shown in blue and north flow in red.

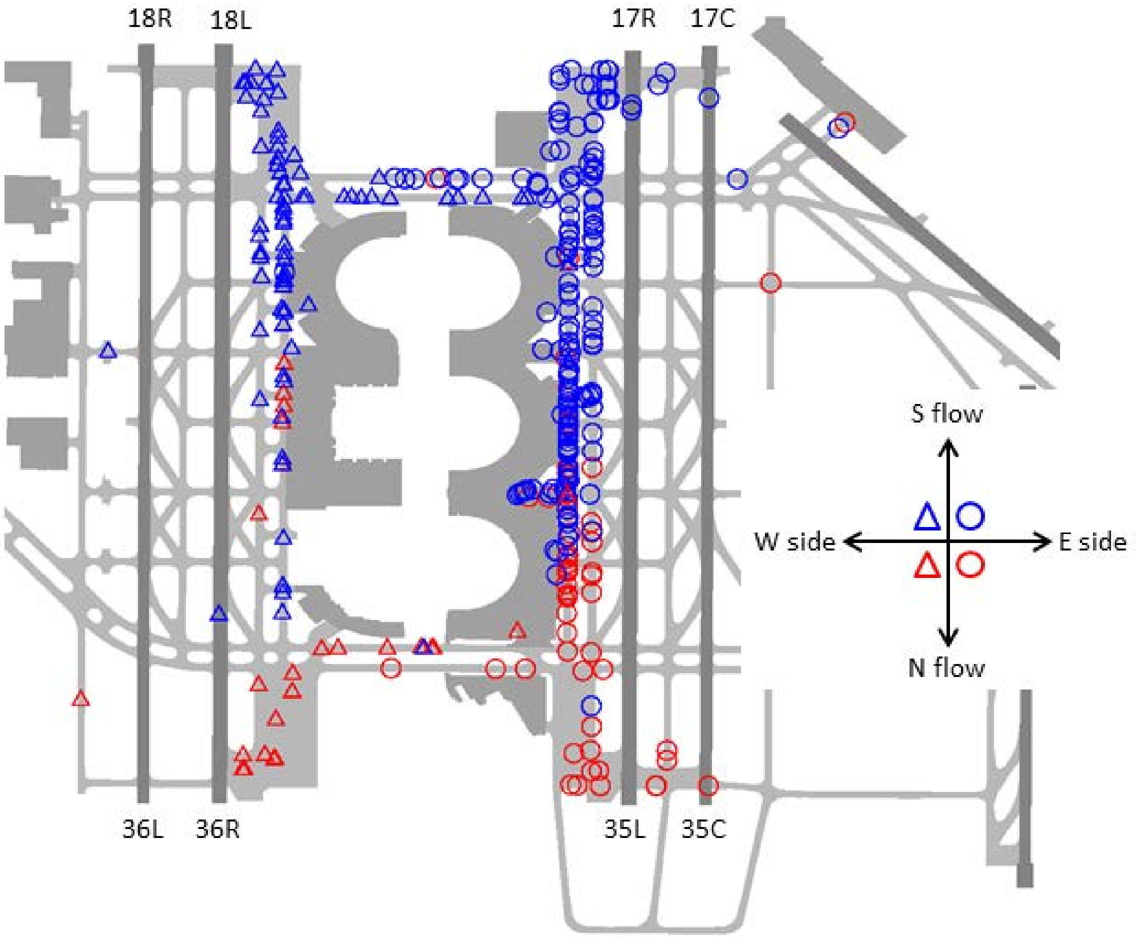


Figure 6:2 – CFR scheduling locations for 342 departures during PDRC Baseline data collection at DFW airport.

This plot represents one year (Nov 2010 – Oct 2011) of tactical departure scheduling operations at DFW.

Figure 6:3 plots the 198 Block 1 & 2 departures on a map of DFW. As before, circles represent flights departing the east side and triangles show west-side departures. In this figure color has been used to distinguish both flow and evaluation block. South flow is shown in either blue or green, while north flow departures are either red or orange. Block 1 flights are shown in blue and red. Block 2 flights are shown in green and orange.

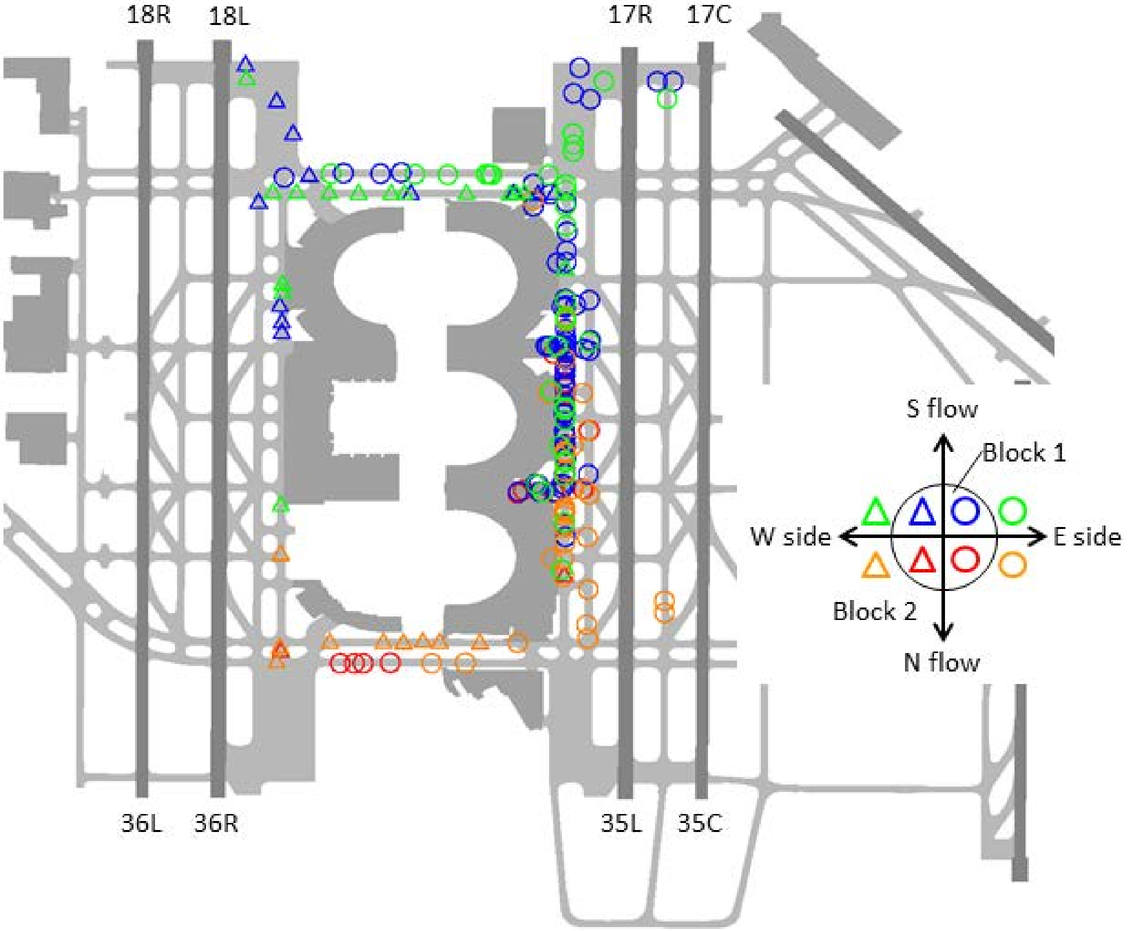


Figure 6:3 – CFR scheduling locations for 198 departures during PDRC Block 1 & 2 operational evaluations at DFW.

A notable difference between Figure 6:2 and Figure 6:3 is the meaning of the position symbols. In both figures the symbols are intended to indicate the point at which the CFR scheduling decision was made. For the Baseline data set the only available information on this decision was the time at which the Center scheduled the departure with TMA/EDC. For the Block 1 and Block 2 flights there was the option of using that same TMA/EDC scheduling event or the time at which the Tower electronically requested the CFR via PDRC. The latter time is plotted due to widespread interest in knowing when and where CFR scheduling decisions are made. A consequence of this data presentation decision is that the figures are not directly comparable – the symbols plotted in Figure 6:2 are from a point later in a flight's progression to the departure threshold than those in Figure 6:3.

Researcher observations, supported by reports from Tower TMCs/FLMs, indicated that CFR scheduling decisions at DFW are typically made at or near the Apron Entry/Exit Point (AEP) or "spot." To reduce clutter, the spots have not been depicted in these figures, but they are located along the outer edges of the aprons where the darker gray of the apron touches the lighter gray of the taxiways. For flights departing on the opposite side from their parking gate, the CFR decision is usually made as they cross the bridge (i.e., taxiways A, B, Y, and Z). The data presented in Figure 6:2 and Figure 6:3 generally confirm these expectations. The Baseline data in Figure 6:2 clearly has a higher percentage of scheduling events on the hold pads near the departure thresholds than does Figure 6:3. One might be tempted to conclude that CFR scheduling was performed later in the Baseline case than with PDRC; however, this difference is more likely attributable to the data source differences described in the previous paragraph. Further analysis is required to determine if there was any real difference in the CFR scheduling decision point between the Baseline and PDRC cases.

These results lead to a consideration of the temporal characteristics of the CFR scheduling process. Table 6:3 presents summary statistics from three time difference (i.e., delta time) calculations that may be useful metrics for the CFR scheduling process. The two left columns present statistics from the Block 1 & 2 evaluations for the delta time between the first surface surveillance track and the Tower Request For Release Time (RFRT). Larger mean and median values are desirable, as this typically indicates earlier scheduling of CFR flights. Earlier scheduling is helpful in finding available slots in the overhead stream earlier and achieving a stable schedule. The significance of the maximum value for this delta time is debatable. An aircraft could be powered up and generating ASDE-X track data for an indefinite period before the Tower chose to initiate an RFRT. However, the minimum values for this delta time are of significant interest for tactical departure scheduling. Surveillance acquisition is a key event for trajectory-based decision support tools like SDSS. With surveillance-based state information predictive accuracy is greatly increased. A closer examination of the data shows only two out of the 198 Block 1 & 2 flights had CFR requests prior to ASDE-X surveillance acquisition.

Table 6:3 – CFR scheduling delta time statistics.

	Tower RFRT minus First surface track		Center schedule minus Tower RFRT		Actual OFF minus Center schedule		
	Block 1	Block 2	Block 1	Block 2	Block 1	Block 2	Baseline
Count	103	95	103	95	103	95	342
Max (sec)	1404	4411	872	562	1203	2607	1461
Min (sec)	-7	-36	0	0	62	79	80
Mean (sec)	187	323	93	60	325	377	369
Median (sec)	125	156	49	42	289	304	345
Std. Dev. (sec)	195	698	138	72	175	328	183

The third and fourth columns in Table 6:3 characterize the delta time between the Tower RFRT and the Center completion of the CFR scheduling action with rTMA/EDC. This is an important metric for tools designed to facilitate CFR coordination. A lower time indicates a faster response by the Center TMC to the scheduling request. The Center CFR scheduling will normally occur some finite delta time after the Tower RFRT. The zero minimum values reflect seven flights (six for Block 1 and 1 for Block 2) where PDRC scheduling was initiated by the Center – in these cases there was no Tower request. As one might expect, as the operational evaluation continued and the TMCs gained familiarity with the PDRC prototype, the Center response time improved and also became more consistent.

The PDRC concept and prototype builds on previous CFR/APREQ coordination research [13, 20, 21] and takes the next step by automatically providing surface trajectory-based OFF time and departure runway predictions. Since the value of automated CFR/APREQ coordination had already been demonstrated in field evaluation [13], the PDRC team elected not to collect additional quantitative baseline data on the manual CFR coordination process at DFW and ZFW. The previous section (Section 6.2) examined the impact of verbal communications uncertainty on CFR coordination.

The last three columns in Table 6:3 show lead time between the completion of the CFR scheduling process and the actual OFF event. This is likely the best metric for comparing CFR scheduling decisions between the Baseline and PDRC cases. The minimum, mean, and median values are all quite comparable between the three cases. The maximum value PDRC Block 2 is about 19 minutes (i.e., 80%) earlier than the maximum value for the Baseline. Before drawing conclusions based upon this difference one must understand that the Baseline data set has been culled to remove OFF time compliance (OTC) outliers beyond one and one-half the interquartile range (i.e., 1.5 x IQR). The Baseline data set culling process is described in Section 6.5. These OTC outliers are the ones most likely to have earlier CFR scheduling decisions. Consequently, the data presented here lead to the conclusion that the CFR scheduling decision point was very similar between the Baseline and PDRC cases. This finding is consistent with expectations since pre-evaluation training stressed that TMCs were not to push for earlier CFR scheduling decisions.

6.4 Subject-matter expert feedback

The subject-matter experts for these evaluations were TMCs, STMCs, and FLMs who used the PDRC prototype while conducting CFR operations at DFW and ZFW. For brevity these test participants will be referred to as TMCs throughout this section. As discussed earlier (Section 5.3), these target-of-opportunity evaluations presented particular challenges to acquiring TMC feedback. Consider that 238 flights were scheduled with PDRC during 29 weeks of Block 1 & 2 evaluations – an average of 8 data points per week on a highly variable schedule. Additionally, more than 40% of these PDRC scheduling events occurred outside of regular work hours (before 8:00am, after 6:00pm, or on weekends). Consequently the PDRC team developed alternative mechanisms for acquiring TMC feedback. These included the NTX technical support hotline, periodic “how goes it” meetings, personal interactions with researchers, and electronic, web-style feedback forms accessible directly from PDRC user interfaces. This section primarily focuses on data collected via the electronic feedback forms.

Screenshots of the electronic feedback forms are shown in Appendix A (Section 9). Figure 9:4 shows the Tower form and Figure 9:5 shows the Center form. These feedback forms were designed to facilitate systematic data collection while keeping the reporting burden as low as possible. The latter point is particularly important as TMCs were being asked to voluntarily provide feedback while conducting tactical departure scheduling operations – by definition a very busy time at their positions. To facilitate communications and promote use of the feedback form mechanism, TMCs were encouraged to use the forms to report any and all feedback and not just ratings. Consequently, only a portion of the submitted forms contained quantitative user feedback for eligible PDRC-scheduled flights.

6.4.1 Identifying eligible ratings

Table 6:4 summarizes all of the feedback forms received during the PDRC operational evaluations. The left half of the table summarizes feedback received for Block 1 and the right half summarizes Block 2. The far left column shows designators for each of the TMCs that submitted feedback. The far right column shows the total number for forms submitted by each TMC. The overall totals are shown on the bottom row – twenty-seven forms were submitted during Block 1 and twenty-three during Block 2 for an overall total of fifty forms.

The second line in the Table 6:4 heading shows that feedback forms were sorted into two categories: those with numeric ratings and those without (i.e., forms reporting PDRC issues). The third line of the Table 6:4 heading shows that the feedback was further categorized by whether or not the submitted form applied to a PDRC-scheduled flight. Fourteen different TMC identifiers are listed in the far left column of Table 6:4. Two of these (DFW5 and ZFW8) represent three forms received from unknown TMCs (i.e., there were no identifiers on the form).

Table 6:4 – Feedback forms received for Block 1 & 2 evaluations.

	Block 1					Block 2					
TMC	issue		rate		total	issue		rate		total	overall
	other	pdrc	other	pdrc		other	pdrc	other	pdrc		
DFW1			1	2	**3**	2				**2**	**5**
DFW2	3				**3**				2	**2**	**5**
DFW3				5	**5**				1	**1**	**6**
DFW4	1				**1**						**1**
DFW5	1				**1**						**1**
ZFW1	1		4	4	**9**	2	1		8	**11**	**20**
ZFW2				1	**1**						**1**
ZFW3				1	**1**						**1**
ZFW4				1	**1**						**1**
ZFW5				1	**1**				1	**1**	**2**
ZFW6				1	**1**				2	**2**	**3**
ZFW7								1		**1**	**1**
ZFW8						1		1		**2**	**2**
ZFW9									1	**1**	**1**
overall	6		5	***16***	**27**	5	1	2	***15***	**23**	**50**

Seven feedback forms (five for Block 1 and two for Block 2) were submitted for flights that did not meet the PDRC scheduling criteria discussed in Section 6.1. Four of these ratings were for flights that did not depart DFW. The rTMA/EDC component of PDRC at the Center was used for tactical departure scheduling from all airports and not just DFW. This feedback was helpful for understanding rTMA/EDC scheduling performance, but the ratings are not directly applicable to PDRC. Of the three remaining ineligible rating forms, two were submitted in situations when only the Center was using PDRC and one was for a situation where the CFR was cancelled prior to departure. That leaves thirty-one eligible ratings (sixteen for Block 1 and fifteen for Block 2) to discuss in the following sections.

Despite some significant PDRC prototype software changes between Blocks 1 & 2, the evaluations were very similar from the TMC's perspective. Thus, the ratings from the two evaluations will be considered together. However, because the Tower and Center forms had different questions they will be discussed separately.

6.4.2 DFW ratings and discussion

This section addresses the DFW ratings for the Block 1 & 2 evaluations. The four ratings questions on this form are shown below. The TMCs were asked to rate each question on a 1 (bad) to 5 (good) scale. Please consult the DFW feedback form screenshot (Figure 9:4) for the exact presentation of the rating scale.

Q1 Was the initial PDRC OFF time PREDICTION reasonable in this situation?
Q2 Was the release time coordinated with ZFW via PDRC acceptable in this situation?
Q3 How did PDRC scheduling EFFORT compare to your baseline procedure?
Q4 Was the PDRC system HELPFUL in this departure scheduling situation?

Five DFW TMCs submitted feedback forms during the Block 1 & 2 evaluations. Table 6:5 shows that three of those five are responsible for the ratings that described below. Each row in the table represents a single feedback form. The four columns on the right correspond to the four questions shown above.

Table 6:5 – DFW feedback.

Date	Callsign	TMC	Q1	Q2	Q3	Q4
Block 1						
06/15/12	SKW5169	DFW1	5	5	2	4
06/15/12	AAL1001	DFW1	3	3	1	2
07/15/12	ASQ4239	DFW3	4	4	2	5
07/15/12	ASQ4209	DFW3	5	5	5	5
07/15/12	AAL1604	DFW3	5	5	5	5
07/15/12	AAL1897	DFW3	5	5	5	5
07/15/12	DAL1675	DFW3	5	5	5	5
Block 2						
12/04/12	AAL1335	DFW3	4	5	5	5
01/09/13	AAL1919	DFW2	1	1	3	1
02/21/13	N769M	DFW2	5	5	5	5
	Count		10	10	10	10
	Average		4.2	4.3	3.8	4.2
	Median		5	5	5	5

Meaningful statistical results cannot be interpreted from such a small sample size; however the average and median ratings for each question are shown to suggest potential trends.

Overall, the ratings are very positive. One that deserves more discussion is the January 9th rating for AAL1919 from DFW2. This particular TMC was highly experienced with the PDRC prototype, and had provided significant valuable feedback throughout the Block 1 & 2 evaluations. The DFW2 feedback prompted an investigation that turned up a lurking software error in SDSS logic that handled coordination of release times with rTMA/EDC. Put simply, the software error would allow coordinated release times to become stale in situations where the Center/Tower scheduling coordination was not promptly completed or where the traffic situation on the surface was very dynamic. The odds of encountering this error were relatively low, and the troubleshooting analysis showed the January 9th situation to be a near worst-case scenario for this logic flaw. A fix for this error was developed, tested, and deployed on January 23rd. Note that DFW2 provided a very favorable rating for the PDRC prototype on February 21st.

6.4.3 ZFW ratings and discussion

This section addresses the ZFW ratings for the Block 1 & 2 evaluations. The four ratings questions on this form are shown below. The TMCs were asked to rate each question on a

1 (bad) to 5 (good) scale. Please consult the ZFW feedback form screenshot (Figure 9:5) for the exact presentation of the rating scale.

Q1 Was the PDRC meter point crossing PREDICTION reasonable?
Q2 Was the final MERGE into the overhead traffic stream acceptable?
Q3 How did PDRC departure scheduling EFFORT compare to baseline TMA?
Q4 Was the PDRC system HELPFUL in this departure scheduling situation?

Nine ZFW TMCs submitted feedback forms during the Block 1 & 2 evaluations. Table 6:6 shows that seven of those nine are responsible for the ratings described below. As in the previous section, the rows in this table correspond to individual feedback forms and the columns to the four questions shown above. Average and median ratings for each question are provided to suggest potential trends.

Note that not every question has been rated on every feedback form. As shown in the feedback form screenshot (Figure 9:5), the form is launched with a default setting of "not rated" for each of the questions. Values of "NR" in Table 6:6 indicate that a TMC elected not to rate that particular question on that form. The TMC had the option to explain the "not rated" in the free-form comments; however, none of these were explained.

Table 6:6 – ZFW feedback data.

Date	Callsign	TMC	Q1	Q2	Q3	Q4
Block 1						
05/10/12	SKW5187	ZFW1	1	5	3	3
05/10/12	ASQ4430	ZFW1	5	5	3	NR
05/20/12	AAL2448	ZFW2	5	5	5	5
06/10/12	AAL1884	ZFW1	NR	4	3	3
06/11/12	DAL2210	ZFW3	1	1	3	1
06/13/12	SKW5173	ZFW4	5	5	3	4
06/19/12	AAL1604	ZFW5	5	5	3	5
07/08/12	TFC3514	ZFW6	1	1	3	1
07/08/12	AAL2362	ZFW1	NR	3	3	3
Block 2						
11/08/12	EGF3219	ZFW1	5	5	5	5
11/14/12	AAL1794	ZFW1	5	5	5	5
11/14/12	DAL865	ZFW1	5	5	5	5
11/18/12	AAL1731	ZFW6	5	5	5	5
11/18/12	AAL1625	ZFW6	5	5	5	5
11/27/12	NKS832	ZFW1	NR	5	5	5
11/27/12	AAL547	ZFW5	5	5	5	NR
12/06/12	EGF3219	ZFW1	5	5	5	5
12/19/12	UAL33	ZFW9	NR	3	3	3
12/20/12	AAL1831	ZFW1	5	5	5	5
12/31/12	UAL249	ZFW1	5	5	5	5
01/10/13	ASQ4674	ZFW1	5	5	5	5
	Count		17	21	21	19
	Average		4.3	4.4	4.1	4.1
	Median		5	5	5	5

Overall, the ratings are very positive; however, a couple of the lower-rated flights deserve a closer look. The June 11th rating for DAL2210 included the following comment:

> A/C WAS RLS WITH A TWO MIN
> DELAY IN THE OVERHEAD
> STREAM SHOULD HAVE BEEN
> TWO MIN LATER DELAY SHOULD
> HAVE ON THE GROUND

Investigation of this issue led to the discovery of an rTMA scheduling software errror. The problem was most pronounced during period of extremely high demand with low capacity, which could be repeated by applying very high MIT (e.g., 50 MIT) on busy streams. The scheduling issue discovered could lead to STA instability, treating a departure flight as an airborne flight and causing errors in the allocated delay. The scheduling issue was resolved and verified by Center personnel. The improved rTMA software was introduced prior to the beginning of the Block 2 operational evaluation.

The July 8th rating for TCF3514 is also worth a closer look. This feedback form included a comment that the overhead stream required a three-minute delay to accommodate this flight. A check of the OFF time compliance shown in Table 12:2 shows actual OFF to be 42 seconds later than the coordinated release time, which is well within the standard –2/+1 compliance window. Analysis of the airborne portion of this flight showed an unusual TRACON flight path that may have contributed to this issue, but there was insufficient data to fully analyze this finding.

Finally, it is worth presenting a day during the Block 1 evaluation when no ratings were submitted. Table 12:2 shows that June 18th was a banner day. Nine flights were scheduled with the PDRC prototype system that day and the OFF time compliance values indicate that the system was performing well. ZFW submitted no feedback forms on this date. A DFW TMC (DFW2) did submit one feedback form. However, this feedback contained no ratings or comments directly relating to the PDRC prototype. DFW2 feedback indicated that UAL1407 could not be tagged up (i.e., registered as an identified target) in the surface surveillance system, which prevented this flight from being scheduled with PDRC. This anecdote highlights the challenges of gathering systematic TMC feedback during target-of-opportunity operational evaluations. An old adage claims that no news is good news, but this is not true from a research data collection perspective. However, the fact that the PDRC prototype was used regularly for a total of 29 weeks with positive feedback (provided via a limited number of forms, the five “how goes it” meetings, and through personal interactions with the TMCs and FLMs) is considered a positive finding.

6.5 OFF time compliance

One objective of the Block 1 & 2 operational evaluations was to demonstrate system performance in real-world operations. The PDRC concept seeks to improve upon schedule compliance by reducing uncertainty inherent in manually computed ready time estimates and manual coordination of release times. Thus, OFF time compliance is an important system performance metric for PDRC.

Preliminary OFF time compliance results comparing Block 1 data to a Baseline data set were reported in Reference 6. The analysis used for that report has been refined and extended to include the Block 2 data. In simplest terms, OFF time compliance (OTC) is the difference between the Coordinated Release Time (CRT) discussed in Section 6.2 and the actual OFF time:

```
OTC = OFF – CRT
```

Negative OTC values indicate departures that were earlier than the Coordinated Release Time. Values for the Coordinated Release Time are easily obtained for both the Baseline and PDRC cases as they are recorded by the TMA/EDC. The challenging aspects of this analysis are detecting the actual OFF event and determining which flights are valid for OTC comparison purposes.

One difference between this analysis and that done for Reference 6 involves the actual OFF time computations for the Baseline data set. The earlier analysis relied on a departure message delivered to TMA/EDC by the Center Host computer. For this analysis, pseudo-OFF times were used as detected from ASDE-X surface surveillance track data by the Surface Operations Data Analysis and Adaptation (SODAA) tool [49]. The SODAA-detected pseudo-OFF times are more comparable to the SDSS-detected pseudo-OFF times used for the PDRC data. Both SDSS and SODAA compute a pseudo-OFF time by detecting start of takeoff roll from surface surveillance data. These values are referred to as “pseudo-OFF” instead of “start-of-roll” to be consistent with SDSS and SODAA parameter naming conventions.

For PDRC OFF time compliance analyses, an OFF time value is preferred that is as close as possible to the time that would have been recorded by the aircraft weight-on-wheels sensor. Section I-G of Reference 6 examines the uncertainty associated with predicting takeoff roll times. In that analysis takeoff roll times (both mean and median) were found to be 38 seconds with a small standard deviation. Since SODAA’s pseudo-OFF time is very close to the start of takeoff roll, a 38-second bias was applied to SODAA pseudo-OFF times to approximate actual OFF for the Baseline data set shown in Table 14:3.

SDSS uses a different algorithm than SODAA does, and it produces pseudo-OFF times that are typically 10–20 seconds after the start of takeoff roll. For this analysis visually-determined OFF times were compared with SDSS pseudo-OFF times for all Block 2 PDRC flights and the difference (both mean and median) was found to be 23 seconds with a very small standard deviation. Thus, a 23-second bias was applied to SDSS pseudo-OFF to approximate actual OFF for the Block 1 & 2 data sets shown in Table 12:2 and Table 13:2. Statistical comparison of the times from OFF to first airborne surveillance track was found to be a useful sanity check for the pseudo-OFF bias values. Mean and median OFF-to-first-track times are within 2 seconds between the Block 1 and Block 2 data sets. Comparing Baseline OFF-to-first-track times to those for Block 1 & 2, the means and medians differ by 9–10 seconds. This difference could be reduced by applying a larger bias to the Baseline pseudo-OFF times; however, there is insufficient data to justify a deviation from the 38 seconds average takeoff roll time reported in Reference 6.

Armed with near apples-to-apples actual OFF time computations, the valid flights for OTC comparison purposes are considered. This process was relatively straightforward for the Block 1 & 2 data sets. The research team observed all flights scheduled during these evaluations, and thus was able to use firsthand knowledge to determine which flights were valid for OTC comparison purposes. For example, one PDRC-scheduled flight that was subject to a CFR procedure was later expedited in order to prevent potential hail damage. At the point that verbal direction was given to expedite the flight, the CFR time was no longer valid. However, no electronic commands were issued for this flight and, had the team not been aware of this occurrence, this flight would have inappropriately skewed the OTC comparisons.

After culling flights where the CFR restriction was explicitly or implicitly removed, any flight subject to a strategic TMI (i.e., flights assigned EDCT times) was removed from the OTC analysis. Flights with EDCTs were not counted in the primary compliance measure because they introduced variation due to procedural differences that were not the focus of this research. Occasionally, individual controllers were observed following different procedures in situations where flights were simultaneously subject to strategic and tactical TMIs.

The culling process was more challenging for the Baseline data set since the firsthand observations were not available. This OTC analysis used the same Baseline data set as in Reference 6. This set was obtained from operational TMA/EDC recordings beginning in November 2010 and running through October 2011. This set included 451 DFW departures that were tactically scheduled with ZFW’s operational TMA/EDC system. Fifty-two of these flights had assigned EDCT times and were removed from consideration per the rationale given above. This left 399 flights in the Baseline dataset as candidates for the OTC comparison.

Use of SODAA for pseudo-OFF detection resulted in 20 additional flights being culled from the Baseline set as these flights did not have the necessary surface surveillance data. A final round of sanity checking removed 8 more flights from the Baseline set because the TMA/EDC scheduling action was deemed to be too close (less than 30 seconds) to the SODAA pseudo-OFF time. This round of culling left 371 flights in the baseline data set.

As noted above with the flight expedited due to hail, many events can effectively cancel a CFR without leaving an electronic record. Given that this large sample of Baseline data covered a long duration in which unknown circumstances might have been involved without a PDRC observer to report them, the outliers beyond 1.5 times the interquartile range (i.e., 1.5xIQR) were removed. This established the outlier cutoffs at +403 seconds and -278 seconds and reduced the baseline data set to 342 flights.

The three data sets used in the OTC comparison are presented in Appendices D, E, and F. As noted above the actual OFF times shown in these tables were computed by applying a bias (either 23 seconds or 38 seconds) to the pseudo-OFF times detected by SDSS and SODAA, respectively. Table 6:7 presents descriptive statistics for the OTC comparison. Since OTC can be either negative or positive, the standard deviation and absolute mean were found to be the most meaningful indicators of system performance. The OTC standard deviation for the Block 1 & 2 sets is approximately 43% lower than the standard deviation for the Baseline set. The OTC absolute mean for Block 1 & 2 is about 43% lower than the absolute mean for the Baseline set.

Table 6:7 – OTC comparison descriptive statistics.

	Baseline	Block 1	Block 2
Count	342	103	95
OTC maximum	376	157	101
OTC minimum	-225	-150	-197
OTC mean (sec, negative is early)	54	19	-9
OTC median (sec)	37	23	1
OTC standard deviation (sec)	115	65	63
Absolute OTC mean (sec)	95	54	51
Comply with -2/+1 min release window (count)	186	76	79
Comply with -2/+1 min release window (%)	54	74	83

Another useful system performance metric is OFF time compliance as commonly measured in present-day NAS operations. In this measure, a flight is said to be compliant if it fits within the standard –2/+1 Coordinated Release Time compliance window [39]. This system performance metric is helpful because it simultaneously captures both the real mean error as well as the variation in a readily-visualized manner. The last two rows of Table 6:7 compare the –2/+1 window compliance results for the Baseline, Block 1, and Block 2 data sets. The results show that 54% of the Baseline flights met the –2/+1 window – remember that this is with outliers removed, as described above. The Block 1 data exhibited 74% compliance against the standard window while Block 2 had 83% compliance. By this performance measure, PDRC Block 2 exhibited approximately 53% improvement over Baseline compliance with the standard window.

Distributions for the three data sets are shown in the following figures. These distributions are plotted as histograms with a bin size of 20 seconds. The distributions have been normalized as percentages (area under the curve sums to 100) to facilitate comparison of distributions with different sample sizes.

Figure 6:4 presents the OTC distribution that corresponds to the mean, median, and standard deviation values presented in Table 6:7. As expected from the descriptive statistics, the Block 1 & 2 distributions are significantly tighter than the Baseline distribution. As noted above, outliers beyond 1.5xIQR (+403 seconds and –278 seconds) were removed from the Baseline data set; however, outliers have not been removed from the Block 1 & 2 data.

This discussion of outliers draws attention to the Block 2 OTC minimum value of –197 seconds shown in Table 6:7 and in Figure 6:4. This data point is 30 seconds beyond the 1.5xIQR cutoff of –166 seconds had the outliers been removed from this data set. However, flights were removed from the Block 1 & 2 OTC analysis only when there was evidence that the CFR had effectively been cancelled or that PDRC scheduling procedures were not being followed. Since this flight departed more than 3 minutes earlier than the PDRC-scheduled release time, it is strongly suspected that the CFR was canceled in this case, but there was insufficient evidence for it to be removed.

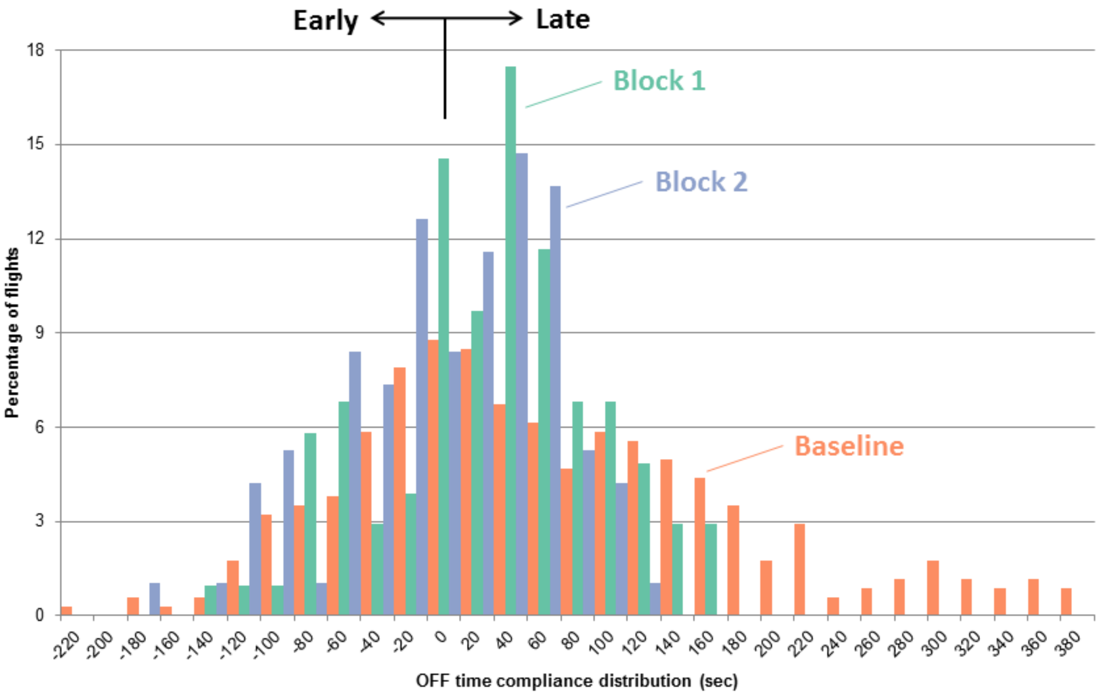


Figure 6:4 – Normalized OFF time compliance distributions for Block 1 and Block 2 evaluations compared to the Baseline data set.

Since OTC may be either positive (late) or negative (early), it is instructive to consider the absolute OTC in addition to the real OTC. The absolute OTC mean values were presented in Table 6:7 with the other descriptive statistics. Figure 6:5 shows the distribution for the absolute OTC. As expected, Block 1 & 2 both show markedly better performance than the Baseline. Comparing the absolute distributions for Block 1 and Block 2, one can see that Block 1 has about 4% more flights in the 20-second bin while Block 2 has 6% more flights in the 40-second bin and more than 6% more flights in the 60-second bin. Counts for the 80-second bin are comparable. While these results appear to favor Block 1 they really highlight a shortcoming off the absolute value OTC measure. In CFR operations, it is generally better to be early than late because it is easier and more fuel efficient for controllers to slow a flight to fit into a slot than it is to speed one up. The absolute OTC measure treats early and late compliance errors equally. Reviewing Figure 6:4, it can be seen that the Block 2 distribution is generally biased earlier than the Block 2 distribution. This is confirmed by the fact that the Block 2 mean value of –9 seconds is 28 seconds earlier than the Block 1 mean value of 19 seconds.

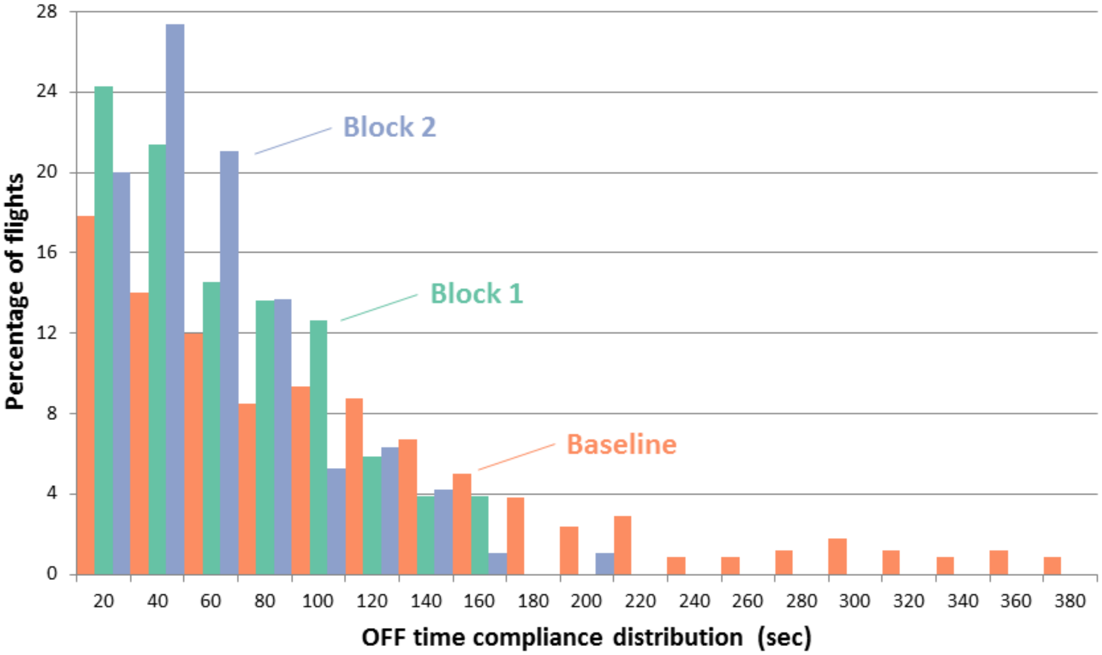


Figure 6:5 – Normalized absolute OFF time compliance distributions for Block 1 and Block 2 evaluations compared to the Baseline data set.

To summarize, PDRC improved tactical departure scheduling performance by reducing the uncertainty the process. The focal point of tactical departure scheduling is the OFF event where the surface trajectory ends and the airborne trajectory begins. This is also the point around which Tower and Center TMCs coordinate release times. Consequently, reducing the OFF time compliance error was a primary objective for PDRC. The OTC descriptive statistics and distributions presented in this section demonstrate that PDRC provides significant improvement over Baseline levels of OFF time compliance.

6.6 Airborne transit time predictions and the ‘hit slot’ metric

The PDRC concept seeks to improve scheduling of tactical departures into available capacity in the en route air traffic flow. This scheduling process encompasses uncertainty in the OFF time as well as airborne transit time prediction, as illustrated by Figure 6:6. The OFF time compliance was discussed in the previous section. This section discusses the airborne transit time prediction accuracy for Block 1 & 2 operational evaluations. The airborne transit time consists of both TRACON transit time and Center transit time uncertainty.

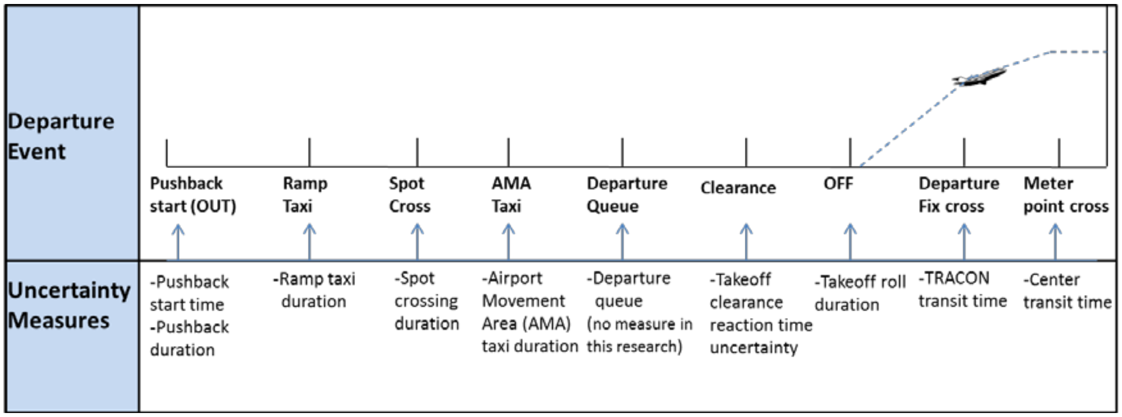


Figure 6:6 – Uncertainty associated with Tactical Departure Scheduling.

At the beginning of the PDRC research activity it was initially assumed that the flight time predictions provided by the en route scheduling system (i.e., TMA/EDC) were sufficiently accurate to enable tactical departures to ‘hit the slot’ reserved in the overhead traffic flow. This assumption was based primarily upon the fact that TMA/EDC was operationally deployed to all Centers and had a reputation among subject-matter experts for accurate flight time estimates. As PDRC research progressed, it was discovered that the error associated with the airborne predictions was more significant than initially envisioned. The first indication of this error came during the shortfalls analysis research [5] in which it was discovered that the majority of flights did not hit the slot they were scheduled into even after the first airborne surveillance. This research, which analyzed all TMA/EDC sites across the NAS for the month of January 2011, indicated that over 60% of flights did not hit the slot predicted by arrival TMA after initial airborne (TRACON and/or Center) surveillance. Thus, the portion of ‘hit slot’ error associated with airborne transit time prediction was significant.

The ‘hit slot’ metric used in the shortfalls analysis [5] revealed a lower percentage of success than expected, however, it did not provide insight into where the error was occurring. By design, the ‘hit slot’ measure emulated what operational Center TMCs do and thus incorporated uncertainty from the departing flight through all phases of flight up to the meter point crossing. The ‘hit slot’ metric also incorporates uncertainty associated with predictions for the leading and trailing aircraft in the overhead traffic flow that the tactical departure is being scheduled between (i.e., uncertainties regarding the slot itself). Therefore if the TMA/EDC airborne transit time prediction was exactly correct to the second, but the predictions for the leading or trailing flights that define the slot were not accurate, the tactical departure would not hit its slot.

To learn more about these ‘hit slot’ metric errors, tools were developed to capture and analyze the information needed to isolate airborne flight time prediction errors. First, the airborne flight metrics were divided into TRACON transit time versus Center transit time estimates. This division was logical because the tactical departure encounters very different traffic situations in these two operational environments. That is, TRACON flight time estimates that terminate at the departure fix are rarely affected by merging/conflicting flights, whereas merging and sequencing commonly have a large impact on Center flight time estimates.

The TRACON transit time is defined as the duration in seconds from wheels OFF to crossing the departure fix, which resides on the boundary of TRACON/Center airspace. A TRACON transit time analysis showed that significant errors may exist in the predicted horizontal flight profiles used by TMA/EDC to compute ETAs at downstream fixes. Results from this analysis were reported in the 2012 AIAA paper [6], and the complete analysis is presented in Appendix B (Section 10).

To briefly summarize, the Appendix B analysis shows large TRACON transit prediction errors due to TMA/EDC's lack of detailed departure routing adaptation within the TRACON. The authors believe that this detailed adaptation was intentionally omitted from TMA/EDC because it depends on knowledge of the specific departure runway. The TMC must manually enter departure runway into the present-day TMA/EDC system. Since this entry is not commonly made, it is logical not to invest in the detailed TRACON departure adaptation that depends on the runway entry. However, with PDRC, the predicted departure runway is automatically and continuously transmitted from the surface system to TMA/EDC. The analysis shows that the PDRC-provided predicted departure runway plus relatively minor TMA/EDC adaptation changes enable significant improvements in TRACON transit time predictions. The results presented in Figure 10:3 show a six-fold reduction in average TRACON transit time prediction error for the largest group of flights affected by this problem. These improvements were incorporated into the PDRC prototype (specifically the rTMA/EDC adaptation) and used for both the Block 1 & 2 operational evaluations.

The uncertainty analysis depicted in Figure 6:6 was conducted in parallel with the Block 1 operational evaluation and documented in the 2012 AIAA paper [6]. This analysis attempted to quantify uncertainty in all phases of the departure process, including the TRACON and Center transit time prediction errors. For the PDRC scheduled flights in the Block 1 evaluation, the mean absolute error was 25 seconds with a median TRACON transit time error of 21 seconds [6]. The mean absolute Center transit time error for all PDRC scheduled flights was 49 seconds with a median error of 32 seconds. Note that the mean error is approximately twice as high for the Center transit time error compared to the TRACON transit time error, despite the fact that the flight distance for these two measures are approximately the same.

As noted in Section 5.4, the PDRC operational evaluations have involved only ***outbound*** tactical departure scheduling using the TMA/EDC decision support tool. Currently, the FAA operates TMA/EDC in an open-loop mode. Unlike arrival metering with TMA, TMA/EDC schedule times and sequence information are not displayed on sector controllers' radar scopes. Center TMCs use TMA/EDC to manage constrained traffic flows in order to provide sector controllers with a workable traffic situation. Sector controllers solve the traffic puzzle with no knowledge of the TMA/EDC planned solution. This has been a significant factor in the high Center transit flight time errors noted in the PDRC evaluations.

Observations of PDRC-scheduled flights and discussions with Center TMCs also revealed other factors, including significant speed fluctuations in the overhead stream, flights that cut corners off of the nominal route, pop-up flights that were scheduled after the PDRC scheduled flights, and altitude error. In the case of altitude error, the primary challenge was that the TMA/EDC predictive models do not reflect the Letter of Agreement between ZFW and ZHU in which aircraft are delivered to ZHU at flight level 290 if IAH is in East flow and flight level 310 if IAH is in West flow. Without this detailed information concerning crossing altitude restrictions, TMA/EDC computes meter point ETAs based on filed flight plan altitudes, which could have significant differences in wind speed and/or take some time to maneuver to.

This discussion of airborne transit time prediction errors can be recapped with reference to the PDRC concept overview diagram (Figure 3:1). PDRC research began with the assumption that the TMA/EDC airborne trajectory (shown as gold in the figure) was acceptably accurate and that the primary contribution to tactical departure scheduling would be to provide a more accurate initial time (i.e., T_0) for this trajectory. The improved initial time for the airborne trajectory would be courtesy of a more accurate predicted final time (i.e., T_F) for the surface trajectory shown in red – a better OFF time prediction. Reduced uncertainty in OFF times has been demonstrated; however, it has also been discovered that more work is required on the airborne side of the problem. Some contributions in this area have been made by using PDRC technology to give TMA/EDC knowledge of the departure runway. Thus, the PDRC prototype improves both the initial time and the initial location (i.e., spatial origin) for the gold airborne trajectory.

However, analysis [6] shows that even these improvements are not enough to suggest use of the airborne ‘hit slot’ metric proposed in the original shortfalls analysis paper [5]. Given the timing associated with widespread deployment of a surface capability that could supply the OFF times required, it is likely better to assume a metering environment in which times are presented to the controllers with tighter tolerances (e.g., ±30 seconds), as has been demonstrated by NASA’s Efficient Descent Advisor (EDA) [10]. Assuming this environment is available along with OFF times and departure runway assignments provided by surface automation, ‘hit slot’ measures taken in a field environment are much more likely to yield improved results.

7 Next steps

This final report and companion documents [1, 2, 4, 5, 6] comprise the PDRC research transition package that NASA will deliver to the FAA to support TFDM and TBFM system acquisition and implementation efforts. This technology transfer will conclude the core PDRC research activity; however, much work remains to be done in the tactical departure scheduling arena. During the course of the PDRC development and evaluation the NASA research team and FAA subject-matter experts and stakeholders developed several compelling ideas for follow-on research. These ideas generally coalesce into three threads: air carrier collaboration, PDRC Enhanced Scheduling, and TRACON Departure Scheduling. Recommendations for future work in these areas will be discussed in the following sections.

7.1 Air carrier collaboration

As shown in Section 6.3, CFR scheduling decisions with PDRC are made at or near the Apron Entry/Exit Point (AEP) or spot, consistent with present-day tactical departure scheduling practices. The 2012 paper on prediction uncertainty [6] examined the feasibility of making the CFR scheduling decision earlier (i.e., moving the decision point closer to the gate). The paper concluded that earlier scheduling with PDRC might be feasible; however, it seems likely that active air carrier participation will be required for effective CFR scheduling in the ramp area.

Active air carrier participation in the management of departure is currently being studied on many fronts, including the NASA Spot and Runway Departure Advisor (SARDA) concept [17], the Surface Collaborative Decision Making effort [34], and the Collaborative Departure Queue Management (CDQM) research [8] led by the FAA's STBO project. Throughout the PDRC research activity NASA has collaborated with the FAA's STBO project to further develop the Tactical Surface Data Exchange (TSDE) interface that was discussed in Section 4.7. With support from FAA STBO, a TSDE interface with American Airlines was developed for the PDRC prototype and this interface provided valuable input for Off-Block Time predictions during the Block 1 & 2 evaluations.

Although TSDE is specified as a two-way interface, the data flow was one-way (air carrier to PDRC) during the Block 1 & 2 evaluations. In parallel with the evaluations, NASA and FAA STBO continued development of the PDRC-to-air carrier side of the TSDE interface. The next steps for this effort will be to share PDRC data elements with air carrier ATC coordinators to assess the value of this information in the air carrier environment.

7.2 PDRC Enhanced Scheduling

Section 6.1.4 summarized a shadow evaluation conducted in March 2013. This evaluation can be described as a series of focus group sessions that used live-traffic shadowing and storyboards to motivate structured interviews concerning PDRC Enhanced Scheduling. This is a collection of ideas that build on the core PDRC concept to further improve tactical departure scheduling by leveraging the power of Center/Tower information exchange demonstrated by PDRC. The ideas are in various stages of maturity, and the purpose of the March 2013 shadow evaluation was to gather subject-matter expert feedback to guide further development of these ideas.

The Enhanced Scheduling ideas are related by the goal to reduce unnecessary CFR constraints, reduce ground delay, improve automation, and enable greater situational awareness. Most of the Enhanced Scheduling ideas center on the new prototype multi-domain "what if" scheduler discussed in Section 4.8. This new software process was used for live-traffic demonstrations of some of the more mature ideas during the March 2013 focus group sessions. The following is a list of the ideas under consideration:

- Early Indication of Tactical Delay
- Size of an Assigned Slot (e.g., Can I Leave Early/Late?)
- Release Flights with a Large Center-Approved Window
- Schedule but Look for a Better Time
- Automatic Scheduling Based Upon Actual OUT Notification
- Center Decision Support Tool for CFR constraint planning

NASA is currently evaluating which of these ideas merit further research.

One of the enhanced scheduling ideas has been developed into a proposed concept for Tactical Departure Scheduling Control by Exception. This new concept seeks to address a shortfall in current-day tactical departure scheduling operations wherein CFR restrictions are applied uniformly over broad time periods, resulting in unnecessary delay to some flights. NASA recently awarded a SBIR Phase I contract to pursue the Control by Exception idea. This research activity will include shortfalls analysis, concept development, identification of required operational metrics, and a concept feasibility assessment.

7.3 TRACON Departure Scheduling

In the introduction, PDRC was described as "a logical step towards the NextGen vision of fully-integrated arrival/departure/surface operations." Tactical departure scheduling coordination between a well-equipped airport Tower and its home Center seemed a logical starting point for several reasons:

- The Center portion of the process was already supported by a widely-deployed decision support tool (TMA/EDC)
- Manually computed and communicated OFF time inputs to TMA/EDC were an obvious shortfall and trajectory-based Tower tools were on the not-too-distant horizon
- Previous research had established the value of automating CFR release time coordination
- Decisions to implement tactical TMIs (i.e., CFR) are local and therefore accessible to the research team

The PDRC concept intentionally focused on applying NextGen trajectory-based technology to a portion of the tactical departure scheduling problem that analysis [5] showed to be commonly occurring in present-day NAS operations. Now that the first step has been taken, other tactical departure scheduling challenges can be addressed by building on the PDRC foundation.

Feedback from stakeholders and experiences conducting the Block 1 & 2 evaluations have strongly suggested that the next step needs to address the challenges of TRACON-level constraints and departures from less-equipped airports. These needs have been a recurring theme in PDRC team interactions with FAA stakeholders dating back to 2010 and they have been reinforced by feedback received from Block 1 & 2 evaluation participants during the PDRC "how goes it" meetings.

Work on the TRACON Departure Scheduling research is currently underway. Section 4.9 discussed new multi-airport capabilities that have been developed to gather quantitative shortfalls analysis data and that will serve as the foundation for a prototype TRACON departure scheduling system. Additionally, NASA observers are spending time on position at D10 TRACON during dynamic weather and traffic events to thoroughly characterize the present-day system and shortfalls. Lessons learned from these D10 observations will be validated with data from other facilities throughout the NAS. Finally, NASA has been coordinating with subject-matter experts and stakeholders to ensure that this new work is well-conceived and aligned with needs. It is expected that this line of research will contribute to future developments for the TBFM Integrated Departure Arrival Capability (IDAC).

8 Concluding remarks

This is the final report for a multi-year concept and technology development and evaluation activity directed towards improving tactical departure scheduling operations. The research commenced with a study of the present-day system to characterize the operation and identify shortfalls. A key finding from this study was that tactically-scheduled departures occur 3.5 times as often as departures subject to strategic constraints. Another key finding was that 25% of flights subject to arrival metering are scheduled into the system as tactical departures while still on the airport surface. This percentage is expected to increase as the TBFM program continues to expand the range of metering through more development of adjacent center metering, coupled scheduling, and extended metering functions.

The initial study identified shortfalls in present-day tactical departure scheduling wherein a significant number of flights missed their reserved slot in the en route traffic flow due to uncertainty in the tactical departure scheduling process. NASA developed the PDRC concept to address these shortfalls and assembled a prototype system to validate the concept and demonstrate system performance in operational field evaluations.

The PDRC prototype utilized a research version of the FAA's operational TMA (rTMA) and a research surface management system (SDSS); the latter served as a surrogate for anticipated NextGen trajectory-based surface decision support tools (e.g., TFDM). PDRC technology development included a two-way interface between rTMA and SDSS. The two-way interface enabled trajectory-based OFF time and departure runway predictions to be delivered from SDSS to rTMA and a full complement of rTMA scheduling information to be delivered to SDSS. The PDRC two-way interface also enabled electronic CFR coordination between the Center TMC and the Tower TMC/FLM.

NASA conducted two operational evaluations of PDRC. The evaluations were based at NASA's NTX Research Station and included participation from TMCs and FLMs at Fort Worth Center and DFW's East and West Towers. The evaluations ran for a total of 29 weeks in 2012 and early 2013. During these evaluations more than 230 flights were scheduled with the PDRC prototype. Positive subject-matter expert feedback was received throughout the evaluation and significant improvements in tactical departure OFF time compliance were demonstrated.

Off-time Compliance (OTC) results from the two PDRC evaluations were compared against a year-long sample of baseline data. Since the goal is to reduce uncertainty, key OTC metrics are the standard deviation and the absolute average error. PDRC showed a 43% improvement over the baseline standard deviation and a 43% improvement in absolute average error.

A key feature of the PDRC concept is coordination and communication based on a single target release time rather than a release window. The PDRC target time (with seconds-level resolution) is used throughout the process and a single time (with appropriate rounding) is communicated by the Tower TMC/FLM to the local controller. When comparing PDRC evaluation results against a present-day standard -2/+1 OFF time compliance window, PDRC Block 2 exhibited approximately 53% improvement over Baseline compliance.

In addition to the new two-way communications interface between rTMA and SDSS, the PDRC research activity produced several other important technology developments and improvements. The PDRC research activity developed rTMA to reduce technology transfer risk and facilitate field evaluations. The rTMA has become an integral element in several other NASA research activities. In collaboration with the FAA STBO office the TSDE air carrier interface was extended and specialized to provide PDRC with data from American Airlines. PDRC research identified improvements in SDSS modeling of Aircraft Movement Area taxi operations to improve OFF time predictions. Analysis of airborne time-to-fly uncertainty uncovered large errors in TMA modeling of TRACON departure routes. New adaptation leveraged PDRC-provided departure runway information to reduce average TRACON time-to-fly prediction errors by up to a factor of 6 (i.e., average errors of 176 seconds reduced to 28 seconds) depending on departure runway and departure fix combination. A new multi-domain, "what-if" scheduler was developed to explore ideas for PDRC scheduling enhancements. Finally, a new multi-airport data processing system was developed to support follow-on research into TRACON departure scheduling.

Acknowledgements

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Reference documents

This section provides a list of references, applicable documents, and related research for the PDRC-IADS research activity. To facilitate document tracking, identical reference lists are being maintained across the PDRC-IADS document family [1, 2, 3]. Consequently, this list should be treated as a bibliography of relevant documents instead of a strict list of references. Documents are listed by category rather than in order of citation, and some documents in the bibliography may not be directly referenced in this document.

PDRC documents:

1. Engelland, S.A., Capps, A., and Day, K., "Precision Departure Release Capability (PDRC) Concept of Operations," NASA/TM-2013-216534, June 2013.
2. Engelland, S.A., Capps, A., Day, K., Robinson, C., and Null, J.R., "Precision Departure Release Capability (PDRC) Technology Description," NASA/TM-2013-216531, June 2013.
3. Engelland, S.A., Capps, A., Day, K., Kistler, M., Gaither, F., and Juro, G., "Precision Departure Release Capability (PDRC) Final Report," NASA/TM-2013-216533, June 2013.
4. Engelland, S.A. and Capps, A., "Trajectory-Based Takeoff Time Predictions Applied to Tactical Departure Scheduling: Concept Description, System Design, and Initial Observations," AIAA-2011-6875, *11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Virginia Beach, VA, September 20–22, 2011.
5. Capps, A. and Engelland, S.A., "Characterization of Tactical Departure Scheduling in the National Airspace System," AIAA-2011-6835, *11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Virginia Beach, VA, September 20–22, 2011.
6. Capps, A., Day, K., Walenciak, E., and Engelland, S.A., "Impact of Departure Prediction Uncertainty on Tactical Departure Scheduling System Performance," AIAA-2012-5674, *12th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Indianapolis, IN, September 17–19, 2012.

Research and technical papers:

7. Atkins, S., Jung, Y., Brinton, C., Stell, L., and Rogowski, S., "Surface Management System Field Trial Results," AIAA 2004-6241, *4th AIAA Aviation Technology, Integration, and Operations (ATIO) Forum*, Chicago, Illinois, September 20–22, 2004.

8. Brinton, C., Lent, S., and Provan, C., "Field Test Results of Collaborative Departure Queue Management," *29th Digital Avionics Systems Conference*, Salt Lake City, Utah, October 3–7, 2010.
9. Cook, L., Atkins, S., and Jung Y., "Improved Prediction of Gate Departure Times Using Pre-Departure Events," AIAA 2008-8919, *26th Congress of International Council of the Aeronautical Sciences (ICAS) including the 8th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Anchorage, AK, September 14–19, 2008.
10. Coppenbarger, R., Dyer, G., Hayashi, M., Lanier, R., Stell, L., Sweet, D., "Development and Testing of Automation for Efficient Arrivals in Constrained Airspace," *27th International Congress of the Aeronautical Sciences (ICAS)*, Nice, France, September 19–24, 2010.
11. de Jonge, H., Tuinstra, E., and Seljée, R., "Outbound Punctuality Sequencing by Collaborative Departure Planning," *6th USA/Europe ATM 2005 Seminar*, Baltimore, Maryland, June 2005.
12. de Jonge, H., Tuinstra, E., and Seljée, R., "Outbound Punctuality Sequencing by Collaborative Planning," NLR-TP-2005-013, National Aerospace Laboratory of the Netherlands (NLR), July 2005.
13. Doble, N., Timmerman, J., Carniol, T., Klopfenstein, M., Tanino, M., and Sud, V., "Linking Traffic Management to the Airport Surface: Departure Flow Management and Beyond," *Eighth USA/Europe Air Traffic Management Research and Development Seminar (ATM2009)*, Napa, CA, June 29 – July 2, 2009.
14. Farley, T. C., Landry, S. J., Hoang, T., Nickelson, M., Levin, K. M., Rowe, D., and Welch, J. D., "Multi-Center Traffic Management Advisor: Operational Test Results," AIAA-2005-7300, *5th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Arlington, VA, September 26–28, 2005.
15. Futato, S., McMillan, K., Callon, S., "TMA En Route Departure Capability Jacksonville ARTCC and Orlando ATCT Usage Data", April 8, 2008.
16. Grabbe, S., "Traffic Management Advisor Flow Programs: an Atlanta Case Study", *AIAA Guidance, Navigation, and Control Conference*, Portland, Oregon, August 8–11, 2011.
17. Hoang, T., Jung, Y., Holbrook, J., and Malik, W., "Tower Controllers' Assessment of the Spot and Runway Departure Advisor (SARDA) Concept," *9th USA/Europe ATM R&D Seminar (ATM2011)*, Berlin, Germany, June 14–17, 2011.
18. Jung, Y. C., and Isaacson, D. R., "Design Concept and Development Plan of the Expedite Departure Path (EDP)," *AIAA Aircraft Technology, Integration, and Operations (ATIO) Conference*, Los Angeles, CA, October 1–3, 2002.
19. Jung, Y., and Monroe, G., "Development of Surface Management System Integrated with CTAS Arrival Tool," AIAA 2005-7334, *5th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Arlington, Virginia, September 26–28, 2005.
20. Kopardekar, P., Green, S., Brinkman, C., Thompson, P., Evans, M., and Davis, D., "Making Internal Departure Release Operations More Efficient," AIAA 2004-6346, *4th AIAA Aircraft Technology, Integration, and Operations (ATIO) Forum*, Chicago, Illinois, September 20–22, 2004.

21. Kopardekar, P., Green, S., and Thompson, P. “Improving Efficiency of Departure Release Communications for En Route Overhead Traffic Flow Management,” *23rd Digital Avionics Systems Conference*, Salt Lake City, Utah, October 24–28, 2004.
22. Krozel, J., Rosman, D., and Grabbe, S., “Analysis Of En Route Sector Demand Error Sources”, AIAA-2002-5016, *AIAA Guidance, Navigation, and Control Conference and Exhibit*, Monterey, California, August 5–8, 2002.
23. Landry, S. J., and Villanueva, A., AIAA-2007-7713, “Mitigating the Effect of Demand Uncertainty Due to Departures in a National Time-Based Metering System”. *7th AIAA Aviation Technology, Integration, and Operations (ATIO) Technical Forum*, Belfast, Northern Ireland, September 18–20, 2007.
24. Palopo, K., Lee, H, and Chatterji, G., “Benefit Assessment of the Precision Departure Release Capability Concept”, *11th AIAA Aviation Technology, Integration, and Operations (ATIO) Conference*, Virginia Beach, VA., September 20–22, 2011.
25. Stein, B., Ceniccola, D., and Vincent, D., “TBFM Coupled Scheduling,” *56th Annual ATCA Conference and Exposition*, National Harbor, Maryland, October 2–5, 2011.
26. Swenson, H. N., Hoang, T., Engelland, S., Vincent, D., Sanders, T., Sanford, B., and Heere, K., “Design and Operational Evaluation of the Traffic Management Advisor at the Ft. Worth Air Route Traffic Control Center,” *First USA/Europe Air Traffic Management R&D Seminar*, Saclay, France, June 1997.
27. Thipphavong, J., and Landry, S. J., “Effects of the uncertainty of departures on multi-center traffic management advisor scheduling.”, AIAA-2005-7301, *5th AIAA Aviation Technology, Integration, and Operations (ATIO) Technical Forum*, Arlington, VA., September 26–28, 2005.

Related NextGen initiatives:

28. MITRE CAASD MTR110240R1 A Concept for Integrated Arrival, Departure, and Surface (IADS) Operations for the Mid-Term, January 2012.
29. MITRE CAASD MTR100349R1 A Functional Analysis of Integrated Arrival, Departure, and Surface (IADS) Operations, March 2012.
30. MITRE CAASD MTR110156R1 Integrated Arrival, Departure, and Surface (IADS): Research Gaps and Recommendations, January 2012.
31. MITRE CAASD MP090230 Surface Trajectory-Based Operations (STBO) Mid-Term Concept of Operations Overview and Scenarios, September 2009.
32. MITRE CAASD MP090169 A Mid-Term Concept of Operations for a Tower Flight Data Manager (TFDM), September 2009.
33. FAA ATO System Operations Services, Operational Concept for Departure Flow Management, June 29, 2007.
34. FAA ATO Surface Operations Office, U.S. Airport Surface Collaborative Decision Making (CDM) Concept of Operations (ConOps) in the Near-Term – Application of Surface CDM at United States Airports, June 15, 2012.
35. FAA, “NextGen Mid-Term Concept of Operations for the National Airspace System,” version 2.1, September 2010.

36. DFM System Requirements, Version 1.0, September 15, 2008.
37. FAA System Wide Information Management (SWIM) http://www.swim.gov/
38. JPDO, "Integrated Work Plan for the Next Generation Air Transportation System," version FY13, http://jpe.jpdo.gov/ee/request/home

Software documents, specifications and standards:

39. FAA NOTICE N JO 7110.612 amends FAA Order JO 7110.65 concerning Traffic Management Advisor (TMA) Departure Restrictions, Clearance Void Times, Hold for Release, and Release Times, January 30, 2013, http://www.faa.gov/documentLibrary/media/Notice/N7110.612.pdf
40. TMA/EDC System/Subsystem Design Description, September 2008.
41. Computer Sciences Corporation, "Traffic Management Advisor (TMA) Interface Control Document (ICD) for the TMA Collaborative Arrival Planning (CAP) Tool," Contract No. DTFA03-02-D-00001, May 31, 2007.
42. FAA ICD NAS-IC-82392403-04, TMA CAP to Volpe's TMA Collector ICD.
43. VNTSC-TFM-07-01, ICD: Flow of TMA Data from Volpe to CDM Participants, V1.6 Draft A.
44. Raytheon, "CTO-05 Surface Management System, CTOD 5-24-1 Final Report," 2004.
45. Louisville SMS User's Guide, Version 7.0, October 16, 2006.
46. FAA IRD NAS-IR-XXXXX, NextGen Surface Prototype System (NSPS) Tactical Surface Data Exchange (TSDE) Interface Requirements Document (IRD), draft version 5.1, January 3, 2013.
47. FAA ConUse, Flight Operator Surface Application (FOSA) Concept of Use, version 1.0, November 30, 2010, draft.
48. FOSA API Overview, Version 1.0, undated.
49. Surface Operations Data Analysis and Adaptation (SODAA) User's Guide, Version 2.10.0, April 30, 2013.
50. ISO 8601, Data Elements and Interchange Formats - Representation of Dates and Times, 2004.
51. RFC 2616, Hypertext Transport Protocol -- HTTP/1.1, June 1999.
52. IEEE-STD 1362-1998, Guide for Information Technology, System Definition – Concept of Operations, 1998.
53. FAA, National Airspace System (NAS) System Engineering Manual, Version 3.1, June 6, 2006.
54. NASA SP-2007-6105, Systems Engineering Handbook, Rev 1, December 2007.

Glossary

This section provides a list of acronyms and terms relevant to the PDRC-IADS research activity. Identical glossaries are being maintained across the PDRC-IADS document family [1, 2, 3].

ADIF	ARTS Data Interface
APREQ	Approval Request – see CFR
ARTCC	Air Route Traffic Control Center – one of twenty FAA facilities responsible for En Route ATC in the NAS
ATC	Air Traffic Control
ATCT	Air Traffic Control Tower
CAP	Collaborative Arrival Planning
CDIF	CAP Data Interface
CDQM	Collaborative Departure Queue Management
CFR	Call For Release – a TMI used to regulate the flow of departures into a constrained overhead stream (also known as APREQ).
ConOps	Concept of Operations
CRT	Coordinated Release Time – the target release time negotiated between Tower and Center during CFR operations (see SDT).
CTD	Concept and Technology Development (NASA Project)
DFM	Departure Flow Management
EDC	En Route Departure Capability
EDIF	ETMS Data Interface
ETMS	Enhanced Traffic Management System – see TFMS
FLM	Frontline Manager
FOSA	Flight Operator Surface Application – see TSDE
GUI	Graphical User Interface
HDIF	Host Data Interface
IADS	Integrated Arrival/Departure/Surface
NAS	National Airspace System
NextGen	The next generation air transportation system
OFF	Aircraft takeoff time
OTC	Off time compliance
PCOT	Predicted Coordinated OFF Time
PDRC	Precision Departure Release Capability

PGUI	Planview GUI
RFRT	Request For Release Time
RMP	Research Management Plan
rTMA	Research TMA
RTT	Research Transition Team – a joint NASA/FAA activity to facilitate NextGen technology transfer
SADD	Schedule a Departure Dialog
SAIE	System Analysis Integration and Evaluation (NASA Project)
SDIF	Surface Data Interface
SDSS	Surface Decision Support System – often used interchangeably with the original SMS name
SDT	Scheduled Departure Time – proposed Coordinated Release Time (see CRT) computed by TMA and communicated to SDSS by PDRC.
SMS	Surface Management System – see SDSS
STBO	Surface Trajectory-Based Operations
TARTS	Terminal Area Radio Telecast System
TBFM	Time Based Flow Management
TFMS	Traffic Flow Management System – replaces ETMS
TGUI	Timeline GUI
TMA	Traffic Management Advisor
TMC	Traffic Management Coordinator
TMI	Traffic Management Initiative
TMU	Traffic Management Unit
TRACON	Terminal RADAR Approach Control
TSDE	Tactical Surface Data Exchange – replaces FOSA

9 Appendix A: Auxiliary Figures

This appendix contains auxiliary figures that are believed to be helpful supplements to the report, but have been located here to improve readability. Some of these auxiliary figures have been excerpted from the companion documents (i.e., ConOps and Technology Description) to facilitate easy reference. In those cases, the figure excerpts include a few paragraphs of descriptive text from the companion document.

9.1 PDRC ConOps Figure 3:1

This excerpt is from section 3.1 of Reference 1.

The study of January 2011 NAS operational data also examined the relative frequency of tactical and strategic departure scheduling. Figure 9:1 uses the large gray ellipse to depict the entire set of domestic flights in the NAS (more than 1 million) for that month. Departures subject to strategic traffic management initiatives are shown in the orange ellipse. Tactical departures are shown in the 3 green ellipses. There were approximately 3.5 times as many tactical departures as strategic departures in January 2011.

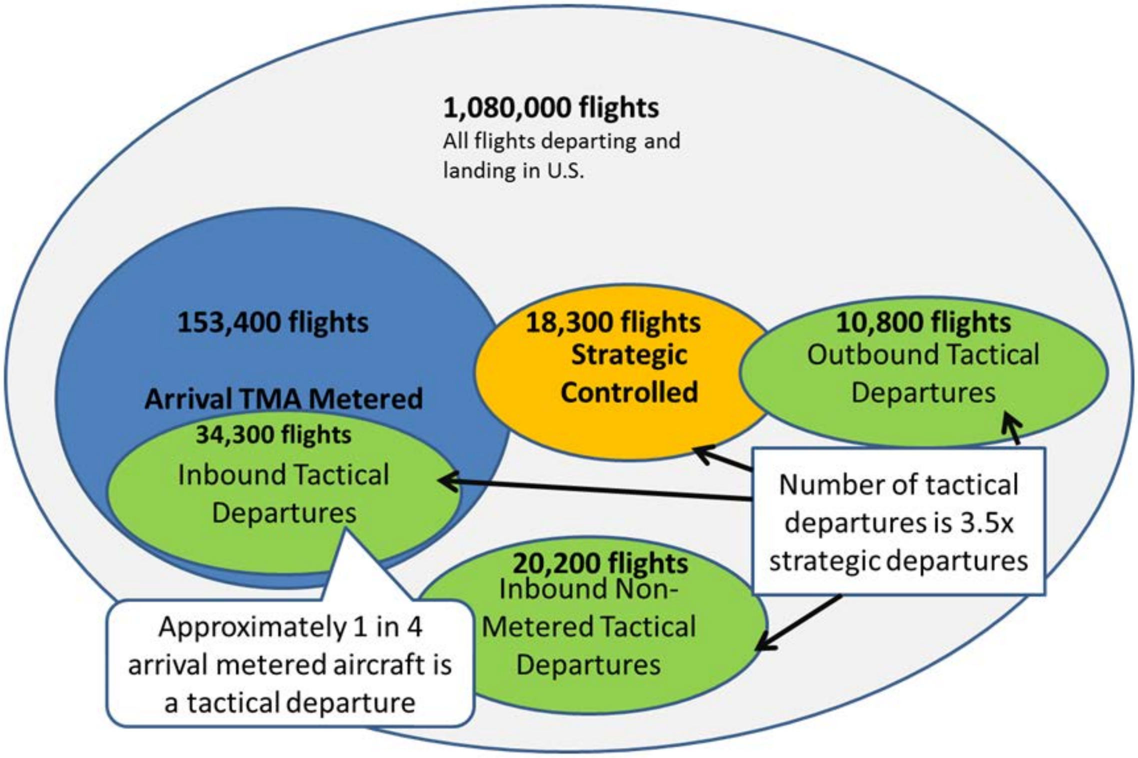


Figure 9:1 – Strategic and tactical departure scheduling for January 2011.

The results shown in Figure 9:1 distinguish between inbound and outbound tactical departures. These two types of tactical departure scheduling are described in detail in Section 3.3. Inbound is associated with TMA arrival metering and outbound is associated with TMA's En Route Departure Capability (EDC) function.

For this analysis, an aircraft was counted as being tactically scheduled only if the aircraft was both scheduled and ‘accepted’ or ‘frozen’ into the TMA Arrival or EDC system. A significant number of aircraft (approximately 18,489 during January, 2011) were initially scheduled in the TMA system, but the scheduling process was not finalized by either “accepting” or “freezing” it. This suggests an even larger pool of tactical departure operations may exist.

It is worth noting that inbound tactical departure scheduling occurred about five times more frequently than outbound tactical departure scheduling in January 2011 operations.

9.2 PDRC Technology Description Figure 3:4

This excerpt is from Section 3.4 of Reference 2.

A high-level diagram of the architecture used in PDRC is depicted in Figure 9:2. This diagram depicts the primary PDRC components involved in a configuration in which a single surface system connects to a single rTMA system. The architecture however is capable of supporting multiple rTMA systems connected to a single SDSS, as well as daisy-chaining data to multiple downstream instances of PDRC.

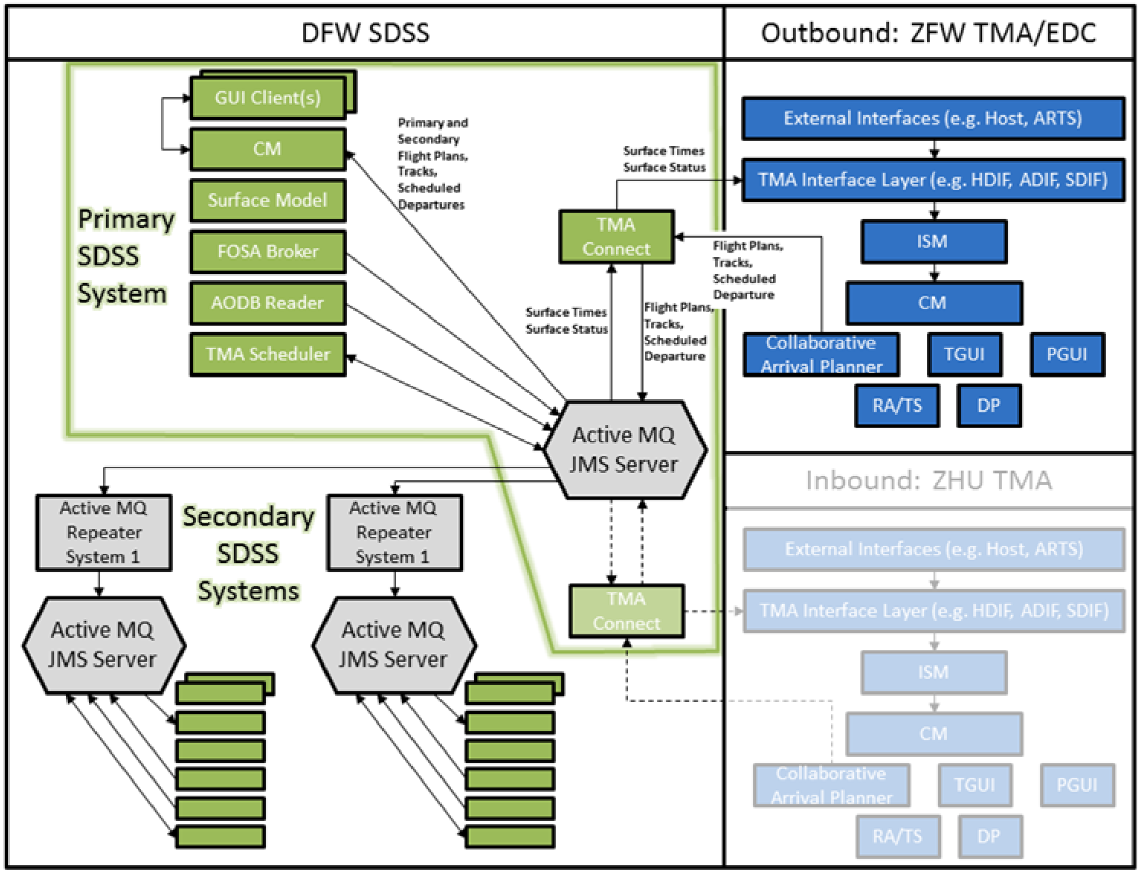
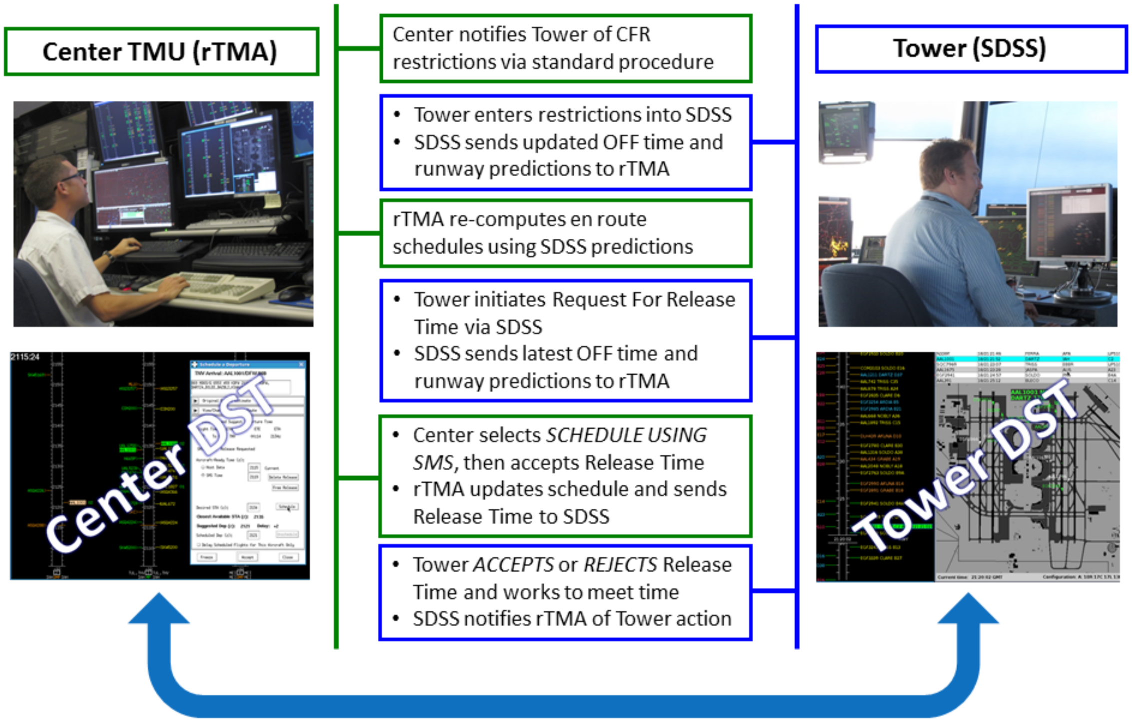


Figure 9:2 – PDRC prototype software architecture

9.3 CFR procedure with PDRC

This excerpt is from section 6.1 of Reference 1.

Figure 9:3 presents an overview of the Tower and Center interactions involved in tactical departure scheduling with PDRC to implement the CFR procedure. The left side of the figure shows the Center TMC interacting with the rTMA user interface. The right side of the figure shows the Tower TMC interacting with the SDSS user interface. Center and Tower TMC actions are listed in the center portion of the figure.



Center notifies Tower of CFR restrictions via standard procedure

- Tower enters restrictions into SDSS
- SDSS sends updated OFF time and runway predictions to rTMA

rTMA re-computes en route schedules using SDSS predictions

- Tower initiates Request For Release Time via SDSS
- SDSS sends latest OFF time and runway predictions to rTMA

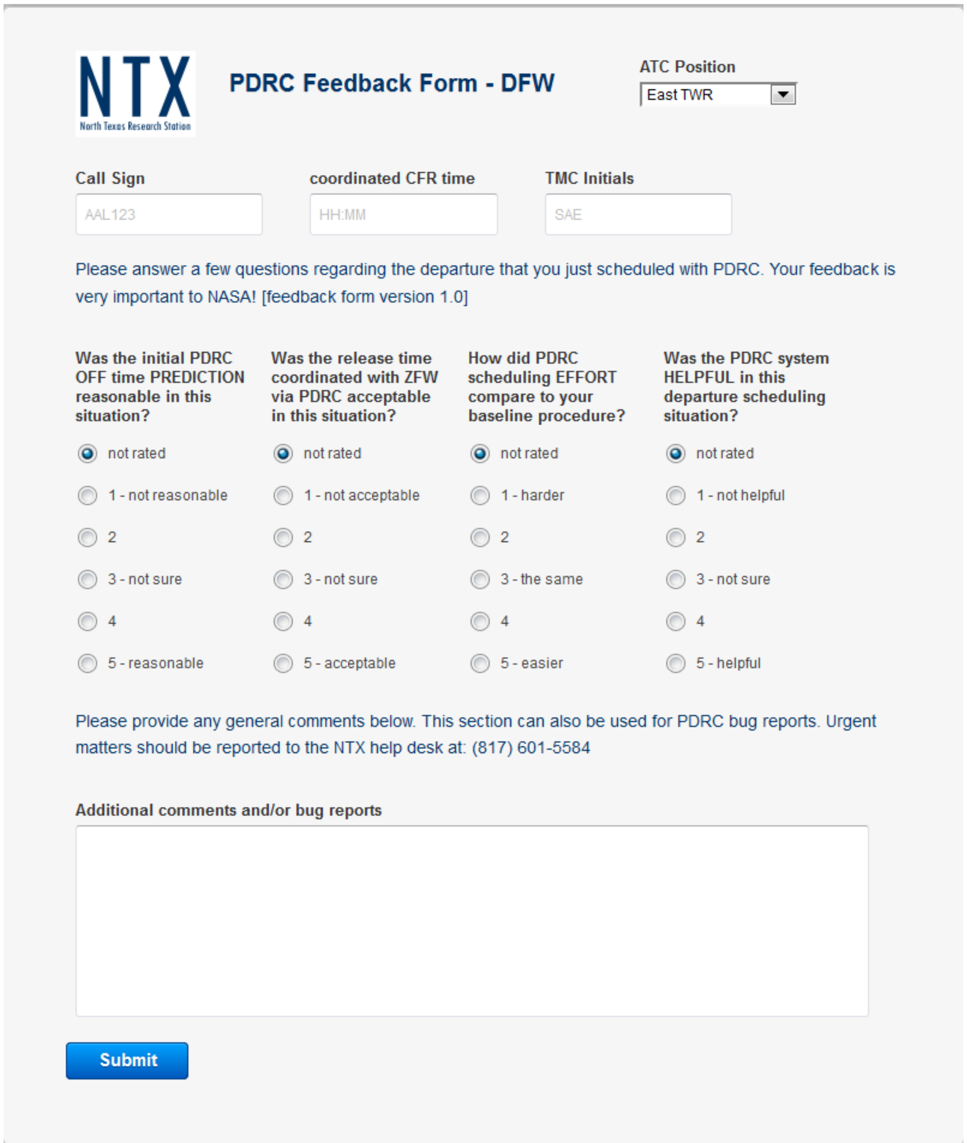
- Center selects *SCHEDULE USING SMS*, then accepts Release Time
- rTMA updates schedule and sends Release Time to SDSS

- Tower *ACCEPTS* or *REJECTS* Release Time and works to meet time
- SDSS notifies rTMA of Tower action

Figure 9:3 – Center and Tower tactical departure scheduling actions with PDRC to implement the CFR procedure.

9.4 TMC feedback forms

This subsection contains screenshots of the electronic forms used to gather feedback from the TMCs, STMCs, and FLMs at DFW and ZFW. These webpage-style forms could be completed directly from the PDRC user interface.



PDRC Feedback Form - DFW

ATC Position: East TWR

Call Sign: AAL123

coordinated CFR time: HH:MM

TMC Initials: SAE

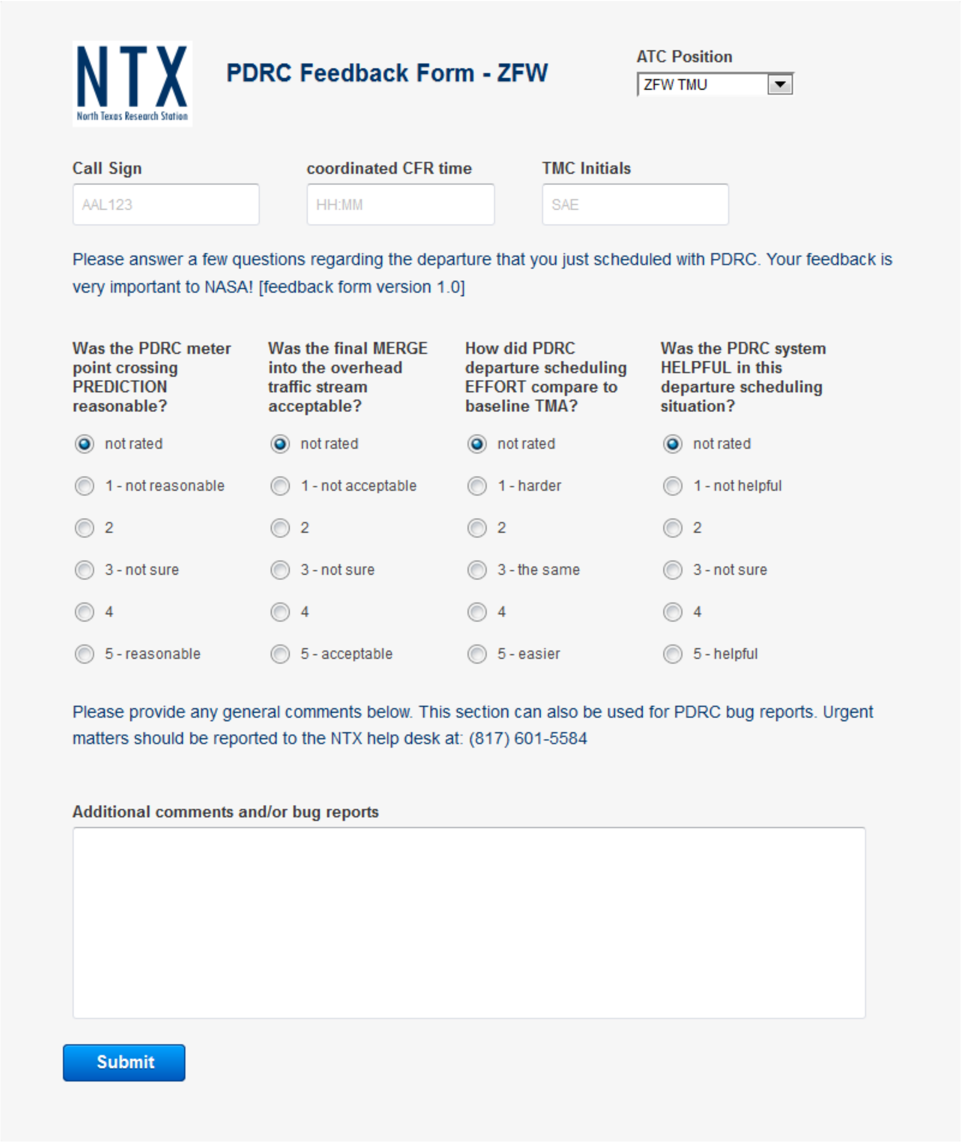
Please answer a few questions regarding the departure that you just scheduled with PDRC. Your feedback is very important to NASA! [feedback form version 1.0]

Was the initial PDRC OFF time PREDICTION reasonable in this situation?	Was the release time coordinated with ZFW via PDRC acceptable in this situation?	How did PDRC scheduling EFFORT compare to your baseline procedure?	Was the PDRC system HELPFUL in this departure scheduling situation?
● not rated	● not rated	● not rated	● not rated
○ 1 - not reasonable	○ 1 - not acceptable	○ 1 - harder	○ 1 - not helpful
○ 2	○ 2	○ 2	○ 2
○ 3 - not sure	○ 3 - not sure	○ 3 - the same	○ 3 - not sure
○ 4	○ 4	○ 4	○ 4
○ 5 - reasonable	○ 5 - acceptable	○ 5 - easier	○ 5 - helpful

Please provide any general comments below. This section can also be used for PDRC bug reports. Urgent matters should be reported to the NTX help desk at: (817) 601-5584

Additional comments and/or bug reports

Figure 9:4 – Feedback form for DFW TMCs, STMCs and FLMs.



PDRC Feedback Form - ZFW

ATC Position: ZFW TMU

Call Sign: AAL123

coordinated CFR time: HH:MM

TMC Initials: SAE

Please answer a few questions regarding the departure that you just scheduled with PDRC. Your feedback is very important to NASA! [feedback form version 1.0]

Was the PDRC meter point crossing PREDICTION reasonable?	Was the final MERGE into the overhead traffic stream acceptable?	How did PDRC departure scheduling EFFORT compare to baseline TMA?	Was the PDRC system HELPFUL in this departure scheduling situation?
● not rated	● not rated	● not rated	● not rated
○ 1 - not reasonable	○ 1 - not acceptable	○ 1 - harder	○ 1 - not helpful
○ 2	○ 2	○ 2	○ 2
○ 3 - not sure	○ 3 - not sure	○ 3 - the same	○ 3 - not sure
○ 4	○ 4	○ 4	○ 4
○ 5 - reasonable	○ 5 - acceptable	○ 5 - easier	○ 5 - helpful

Please provide any general comments below. This section can also be used for PDRC bug reports. Urgent matters should be reported to the NTX help desk at: (817) 601-5584

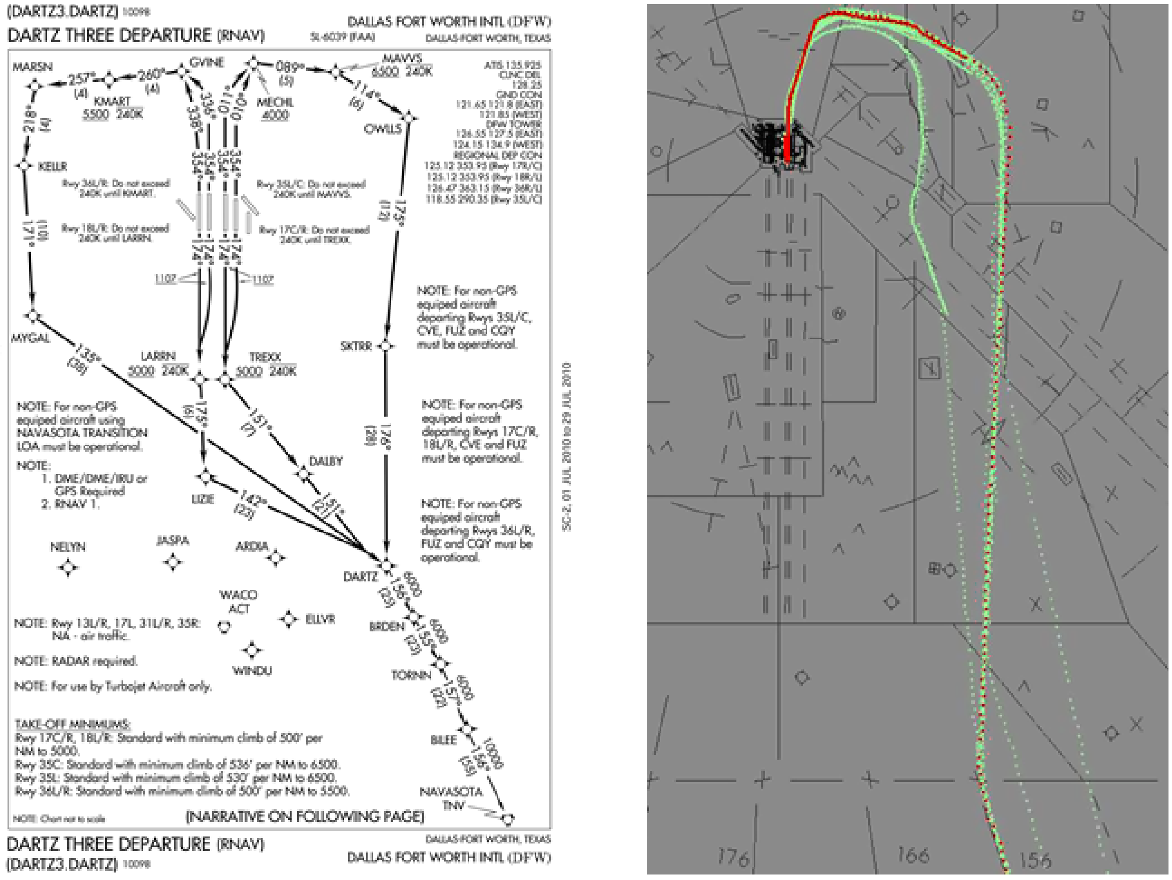
Additional comments and/or bug reports

Figure 9:5 – Feedback form for ZFW TMCs and STMCs.

10 Appendix B – TRACON transit time prediction improvement

This appendix presents analysis conducted in Nov-Dec 2011 that supported improvements in rTMA predictions of TRACON transit time. Highlights from this work were published in Reference 6, but the complete analysis has not been published before now. The purpose of the departure route adherence accuracy metric is to assess the predicted horizontal departure route versus the actual route the flights follow and determine the effect such differences may have on flight time estimates.

Analysis of departure route prediction accuracy was performed on departures to Houston Intercontinental (IAH) which is the tactical departure route associated with the highest departure delay at DFW. For this route, DARTZ is the DFW departure fix and is the easternmost fix on the south departure gate of D10 TRACON. The primary departure route filed for the DFW to IAH departure is the DARTZ RNAV. The departure procedure is shown in Figure 10:1(a).



(a) DARTZ3 DFW RNAV departure procedure.

(b) Flights from Nov 1-6, 2011 using the DARTZ3 departure procedure.

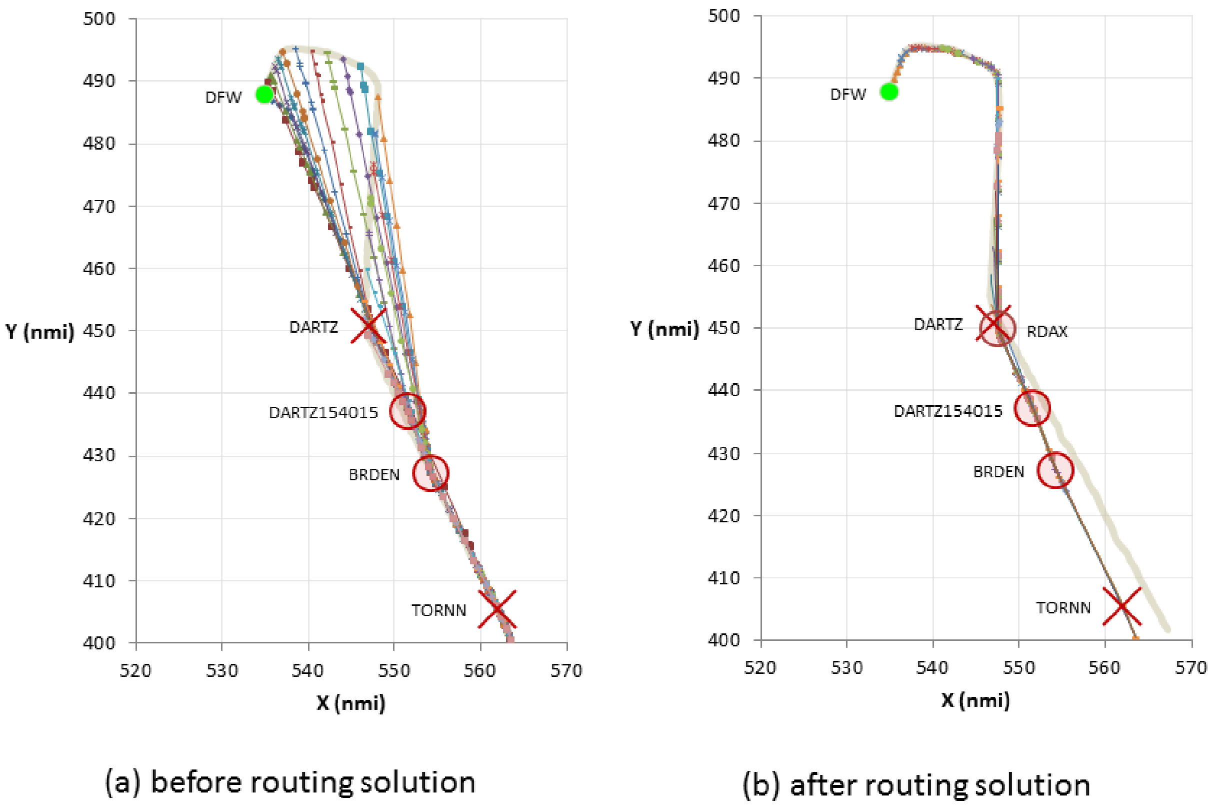
Figure 10:1 – DARTZ3 DFW RNAV departure procedure.

Note that the DARTZ3 procedure is no longer current. Since this analysis was performed with DARTZ3 data, the older departure procedure plate will be used to be consistent with the data. Figure 10:1(b) illustrates actual departure traffic that flew the DARTZ3 departure route in the

Nov 1–6, 2011 timeframe. The red track is of AAL1560, which is a representative nominal flight used throughout this analysis.

10.1 The problem

Currently, departure logic in PDRC's TMA/EDC component predicts that the flight will fly an adaptable number of nautical miles in the direction of departure and then acquire the first departure fix in the departure route. Analysis of the DFW departure data revealed that the first fix was significantly downstream in the aircraft's route of flight. Due to this, the en route transit time predicted by TMA/EDC assumed that the flight would head directly toward this fix instead of capturing the nominal waypoints along the RNAV departure route. Figure 10:2(a) illustrates the horizontal profile of the TMA/EDC predictions for the AAL1560 flight mentioned earlier. The predictions for AAL1560 are representative of the current operational system logic. In this diagram, DFW is the green dot and DARTZ (red X) is the first fix in TMA's estimated route. The thick, dull gray line is the actual track. The various colored lines that extend from the gray route are the TMA/EDC provided estimated routes at each point in time. Ideally the colored lines would overlay the thick gray route as they do in the Figure 10:2(b) "after" plot.



(a) before routing solution

(b) after routing solution

Figure 10:2 – TMA departure route predictions before and after implementation of an adaptation-based solution.

Figure 10:2(a) illustrates the problem from a route geometry perspective, but it does not reflect the impact to the estimated time of arrival. To determine ETA impacts, the actual fly time was taken for a sample of 109 flights from DFW to IAH. Figure 10:3 plots the difference between the actual and estimated fly times taken at first track to the TRACON departure fix (DARTZ). The data in this figure is stratified by departure runway – runway 35 departures are plotted on the left while runway 36 departures are plotted on the right. The actual transit time was defined as the time between the first radar track and the time when the flight crosses the departure fix.

The "before" data is plotted as blue diamonds for both runways. The green triangles show "after" data and will be discussed later. The red X symbols show the average TMA Estimated Time-of-Arrival (ETA) error for each of the data sets.

Figure 10:3 shows that ETAs for Runway 35 departures exhibited a mean error of 176 seconds prior to the solution. The "before" sample size for Runway 36 is quite small; however, the two data points are tightly clustered near 235 seconds of ETA error.

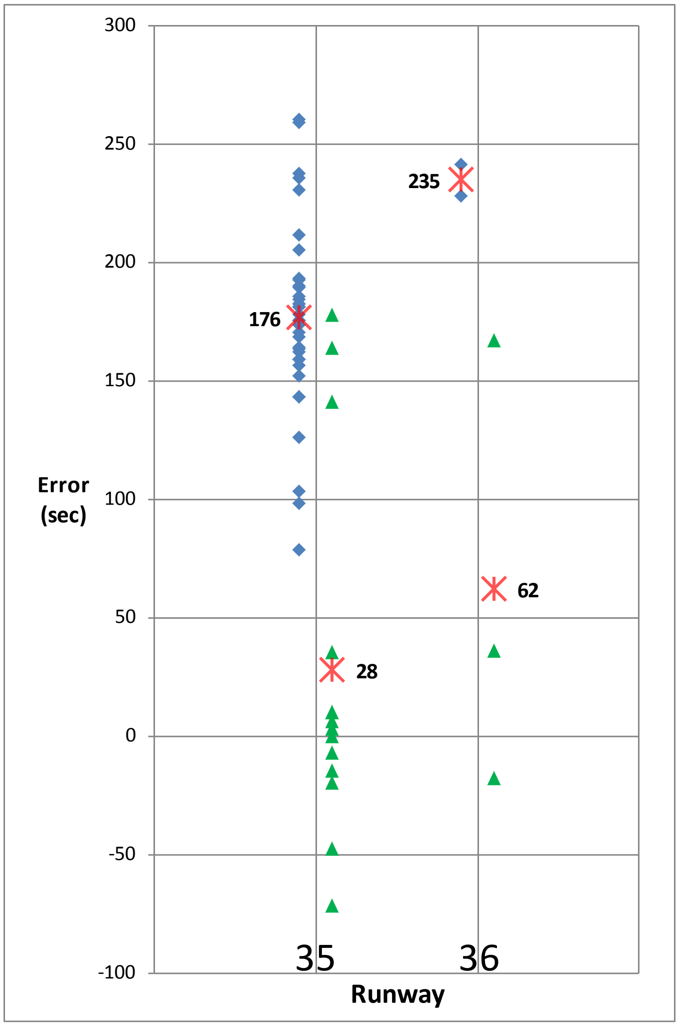
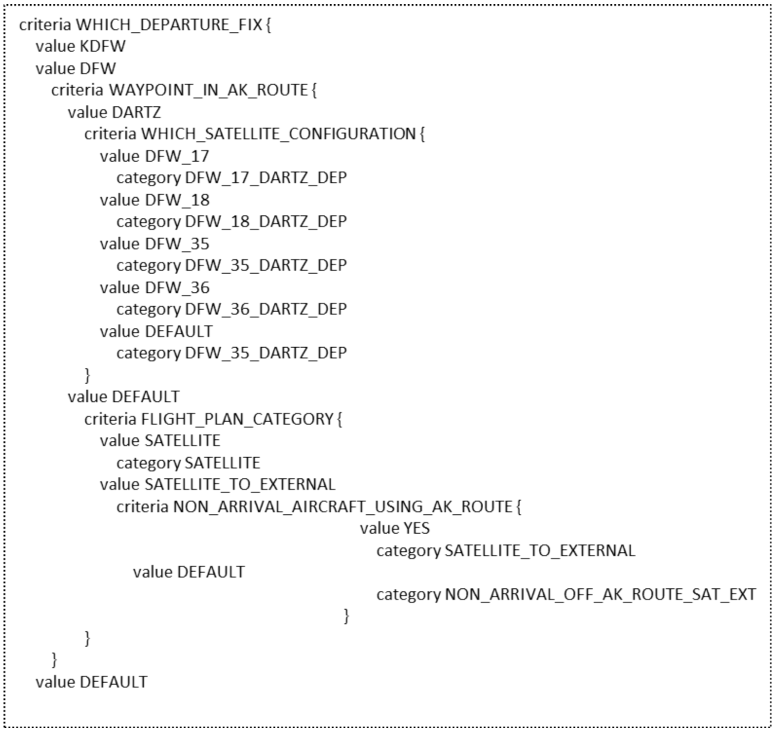


Figure 10:3 – TMA ETA error before and after adaptation solution.

10.2 The solution

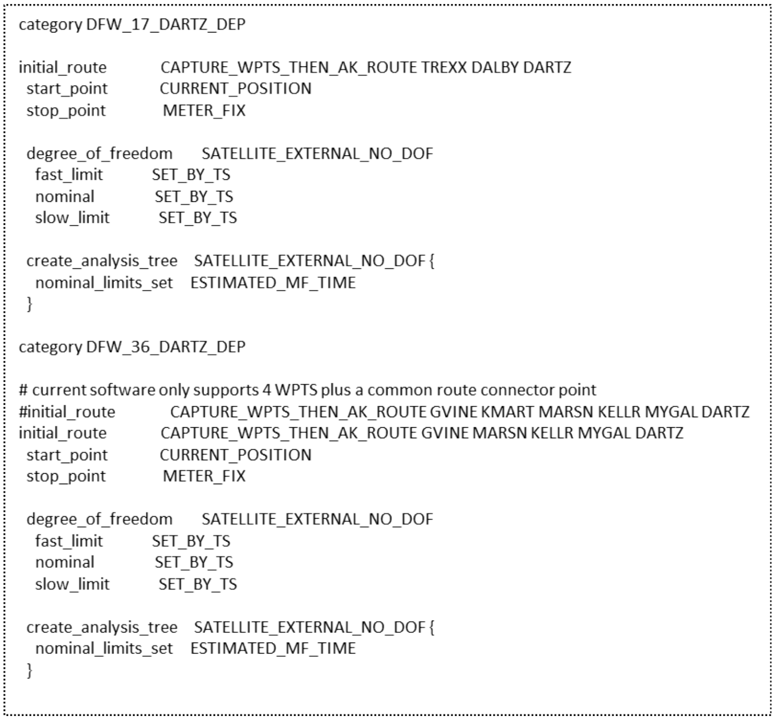
Reducing routing error within the TRACON is straightforward – simply have rTMA implement the expected departure procedures. The challenge is how to implement the departure procedures. The solution selected was to create a more specific departure routing that includes the expected TRACON departure fixes from the RNAV departure route. The routing assignment in adaptation was linked to the departure runway, which is automatically passed to TMA/EDC from PDRC's SDSS component.

The solution leverages existing capability within the rTMA analysis_categories and category_definitions adaptation files (with a change also made to the initial heading/distance values in satellite_category_definitions). There are some downsides to this approach. The number of points (fixes) in the route is limited, and the solution diverges from how other arrival/departure procedures are implemented within rTMA. Figure 10:4 (analysis_categories) and Figure 10:5 (category_definitions) provide an example of the solution for the DARTZ3 RNAV departure procedure.



```
criteria WHICH_DEPARTURE_FIX {
  value KDFW
  value DFW
    criteria WAYPOINT_IN_AK_ROUTE {
      value DARTZ
        criteria WHICH_SATELLITE_CONFIGURATION {
          value DFW_17
            category DFW_17_DARTZ_DEP
          value DFW_18
            category DFW_18_DARTZ_DEP
          value DFW_35
            category DFW_35_DARTZ_DEP
          value DFW_36
            category DFW_36_DARTZ_DEP
          value DEFAULT
            category DFW_35_DARTZ_DEP
        }
      value DEFAULT
        criteria FLIGHT_PLAN_CATEGORY {
          value SATELLITE
            category SATELLITE
          value SATELLITE_TO_EXTERNAL
            criteria NON_ARRIVAL_AIRCRAFT_USING_AK_ROUTE {
                                              value YES
                                                category SATELLITE_TO_EXTERNAL
              value DEFAULT
                                                category NON_ARRIVAL_OFF_AK_ROUTE_SAT_EXT
                                            }
        }
    }
  value DEFAULT
```

Figure 10:4 – rTMA analysis_categories for implemented solution.



```
category DFW_17_DARTZ_DEP

initial_route          CAPTURE_WPTS_THEN_AK_ROUTE TREXX DALBY DARTZ
  start_point          CURRENT_POSITION
  stop_point           METER_FIX

  degree_of_freedom      SATELLITE_EXTERNAL_NO_DOF
    fast_limit         SET_BY_TS
    nominal            SET_BY_TS
    slow_limit         SET_BY_TS

  create_analysis_tree    SATELLITE_EXTERNAL_NO_DOF {
    nominal_limits_set    ESTIMATED_MF_TIME
  }

category DFW_36_DARTZ_DEP

# current software only supports 4 WPTS plus a common route connector point
#initial_route          CAPTURE_WPTS_THEN_AK_ROUTE GVINE KMART MARSN KELLR MYGAL DARTZ
initial_route          CAPTURE_WPTS_THEN_AK_ROUTE GVINE MARSN KELLR MYGAL DARTZ
  start_point          CURRENT_POSITION
  stop_point           METER_FIX

  degree_of_freedom      SATELLITE_EXTERNAL_NO_DOF
    fast_limit         SET_BY_TS
    nominal            SET_BY_TS
    slow_limit         SET_BY_TS

  create_analysis_tree    SATELLITE_EXTERNAL_NO_DOF {
    nominal_limits_set    ESTIMATED_MF_TIME
  }
```

Figure 10:5 – rTMA category_definitions for implemented solution.

A final note about the PDRC implementation of TRACON departure routing is appropriate. The PDRC solution implemented the routes using decision_tree logic simply because it was the quickest, no-software-change solution that would suffice, albeit with limitations. It is the norm, however, for rTMA routing to be directly derived from the Host Computer System (HCS) adaptation and more specifically from the HCS files PAR, PDR, and PDAR (preferred arrival route, preferred departure route, and preferred departure/arrival route, respectively). These are implemented in rTMA as nas_pars, nas_pdrs, and nas_pdars. The TRACON departure routes are contained within PDAR, but since this is Center adaptation, the first fix in the route begins at the departure fix and thus does not include the interior TRACON fixes. A suggested final implementation is to use the same or similar syntax as found in the nas_pdars file for a TRACON departure routes file. This would allow reuse, with slight modifications, of the existing software ingest and all of the associated route processing logic.

10.3 Results

The “after” portions of previous figures will now be examined to see the effect of implementing the interim, adaptation-only solution in rTMA. Figure 10:2(b) provides a graphical view of rTMA route predictions for a DFW departure after implementing this solution. As illustrated, the predictions and the actual tracks align closely. When compared with the “before,” immediately to the left, the improvement is striking.

However, the horizontal route predictions are only a means to computing ETAs at downstream fixes. The green triangles in Figure 10:3 show the difference between the actual time of flight and the TMA predicted time of flight to the departure point after the solution was implemented. The “after” data sample consists of 53 flights. Mean ETA error for runway 35 departures has been reduced from 176 seconds to 28 seconds. Runway 36 demonstrated similar improvement, with a mean error of 235 seconds prior to the routing solution that was reduced to 62 seconds after the solution.

11 Appendix C – AMA taxi time prediction improvement

This appendix presents research performed to improve SDSS predictions of Aircraft Movement Area (AMA) taxi times. This work has not been published elsewhere. The specific objective of this work was to determine the best possible speed to use when modeling departure taxi operations in the AMA.

11.1 Approach

A multivariate regression analysis methodology will be used. The dependent variable will be the spot-to-queue taxi time (AMA), with independent variables being aircraft type, carrier, spot group, runway. The independent variables to form a matrix of possible factors that influence AMA taxi time. The best possible speed will be the one that reduces the spot-to-queue taxi time error, as well as the standard deviation of that error. The current default taxi speed used by SDSS for all departure flights is 17 knots.

To find the best possible AMA taxi speed to use, first the difference in predicted spot-to-queue taxi time and actual spot-to-queue time is minimized. The actual spot-to-queue time is defined as the Queue Entry Time minus the Spot Crossing Time. The Spot Crossing time is the time at which the flight crosses the spot and enters the Aircraft Movement Area. The Queue Entry time is the first time at which the flight status changes in SDSS to "In Queue." The predicted spot-to-queue time is derived using the TrajectoryDashboard-1.0 tool – an analysis companion to SDSS. This returns a set of intersections, time and distances from each gate node to each runway. The values of interest correspond with the spot to the queue entry polygon, but there is no intersection that rests exactly at the entry of the queue polygon. To solve this problem, the intersection closest to the queue entry polygon is used, and then a buffer distance is added or subtracted to end up with the exact distance (using the node-link SDSS model) from the spot to the queue entry. An example of how this is done is shown in the following section.

11.2 Determining Spot-to-Queue Distances

Table 11:1 shows a set of intersections and distances from the TrajectoryDashboard-1.0 tool. The geometry for this example is shown in Figure 11:1. The intersection closest to the queue entry polygon is found. In the example shown, this is intersection "L-Y". The total spot-to-queue distance is "distance at L-Y" minus "distance at "A-010-K5" (spot) minus distance between queue polygon and intersection "L-Y". These "buffer" distances are stored for each route, and then applied during the calculation of predicted AMA taxi times. To derive the taxi time, simply divide distance by speed. This allows insertion of different values for the speed to determine which one will minimize error.

Table 11:1 – TrajectoryDashboard values (gate A19, spot 10, rwy 17R)

Intersection	Distance (nm)
A19	0
A0035	0.0515
K-K5	0.0818
A-010-K5	0.1097
K-009-A	0.1459
K-Z	0.2888
Z-new2	0.3061
Z-ZA-0	0.3227
Z-ZA-1	0.3312
Z-ZA-2	0.3398
Z-ZA-3	0.3494
L-Z-ZA-4	0.3589
L-Z-ZA-2	0.3789
L-Y	0.3997
L-EH	0.6441
EH0-4	0.7168
EH0-3	0.7296
EH0-2	0.7384
EH0-1	0.7475
EH0-0	0.7585

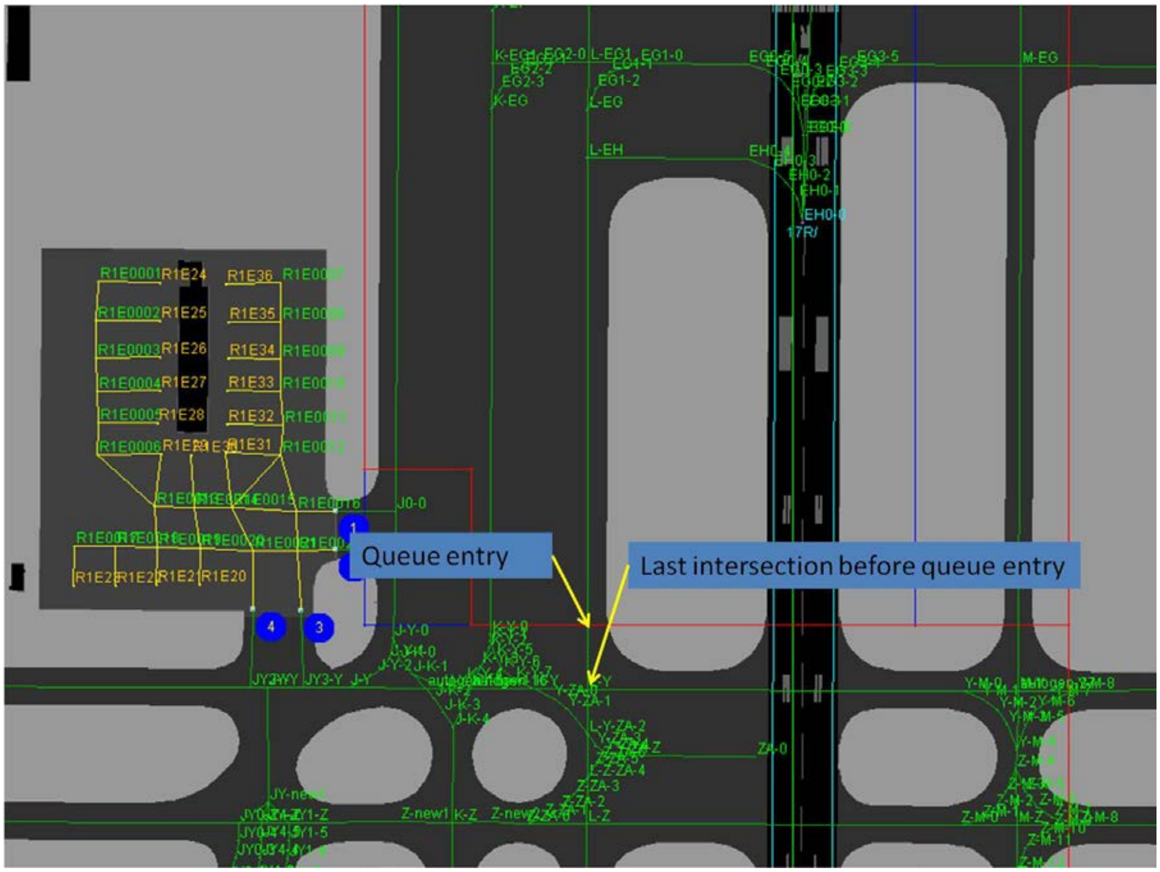


Figure 11:1 – Locating the queue entry for DFW runway 17R.

To find the set of speeds that minimize AMA taxi time error and standard deviation, actual flight data are categorized by different combinations of aircraft type, carrier, runway, and spot groups (ramp areas). This analysis will be explained in the next section.

11.3 Determine AMA Speeds by Groups

To determine AMA taxi speeds for use in this analysis, actual flight data is taken from 11/5/2012 to 12/13/2012. The data is split into training and test sets. The training set is used to derive speed values, which are then used by the test set to determine the error in predicted and actual spot-to-queue taxi times. The test set, which was chosen at random, contains flight data from the days listed in Table 11:2.

Table 11:2 – Test Set Data

Day	Departure Flight Count
11/13/2012	418
11/14/2012	440
11/17/2012	379
11/24/2012	377
11/27/2012	452
12/03/2012	453
12/11/2012	413

Using the training set, data is grouped using the categories listed in Table 11:3 below. For each unique category grouping, the median spot-to-queue taxi speed is stored. This value is then applied to the test data set to determine the difference in predicted and actual spot-to-queue taxi time.

Table 11:3 – Grouping Variables

Group #	Group Variables
1	N/A (default 17 knots)
2	Aircraft Type
3	Aircraft Type, Runway
4	Aircraft Type, Runway, Spot Group
5	Aircraft Type, Spot Group
6	Carrier
7	Carrier, Aircraft Type
8	Carrier, Aircraft Type, Runway
9	Carrier, Aircraft Type, Runway, Spot Group
10	Carrier, Aircraft Type, Spot Group
11	Carrier, Runway
12	Carrier, Runway, Spot Group
13	Carrier, Spot Group
14	Runway
15	Runway, Spot Group
16	Spot Group

11.4 Data Filters

Filters are applied to the actual flight data to ensure the predicted and actual spot-to-queue taxi times are relevant to the analysis. The following filters are applied:

- Actual spot crossed must not be <null>
- The predicted runway at time of spot crossing must equal the actual runway used
- The predicted spot at time of spot crossing must equal the actual spot used
- The flight must not have an EDCT associated with it

11.5 Results

The results of the analysis are shown in this section. From these results the variable grouping with the minimum error and standard deviation is chosen as the new set of AMA taxi speeds to be used by SDSS.

Figures 11:2 and 11:3 show the real and absolute error in AMA taxi times as a box plot. The variable combination number can be linked to the category grouping in Table 11:3. A visual check of the data shows that each combination performs better than the default 17 knots by bringing the mean and median error near 0. The default 17 knots return an error closer to -30 seconds. Also, the absolute error appears to be reduced. A more detailed depiction of the mean, median, standard deviation, and inter-quartile range are shown later in this section to facilitate choosing the category grouping with the most improved performance.

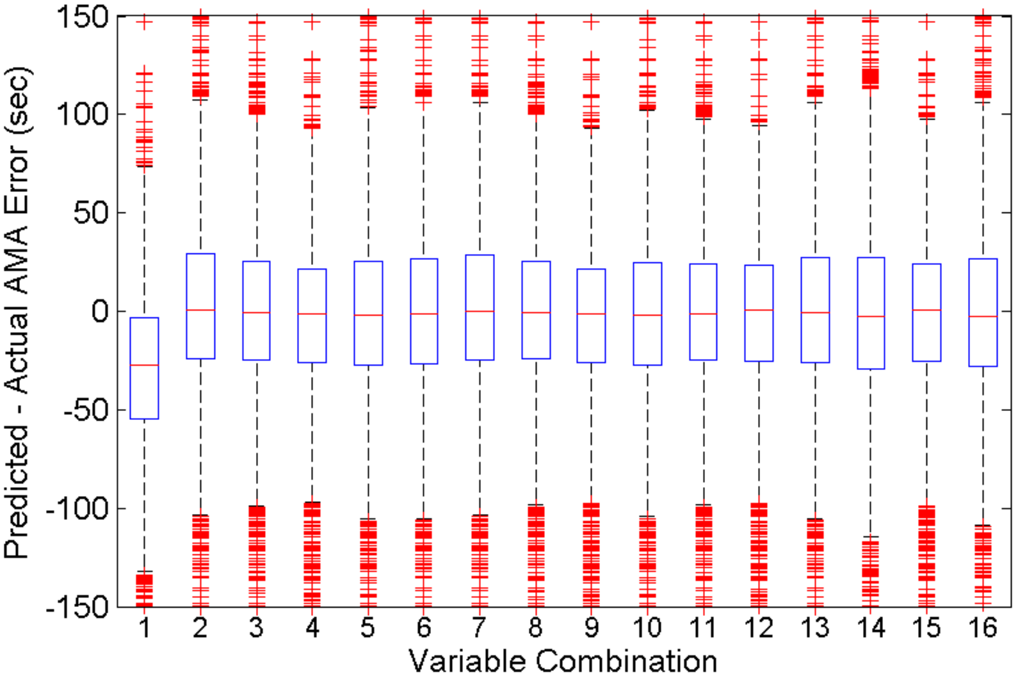


Figure 11:2 – Box plot of Real AMA Taxi Time Error

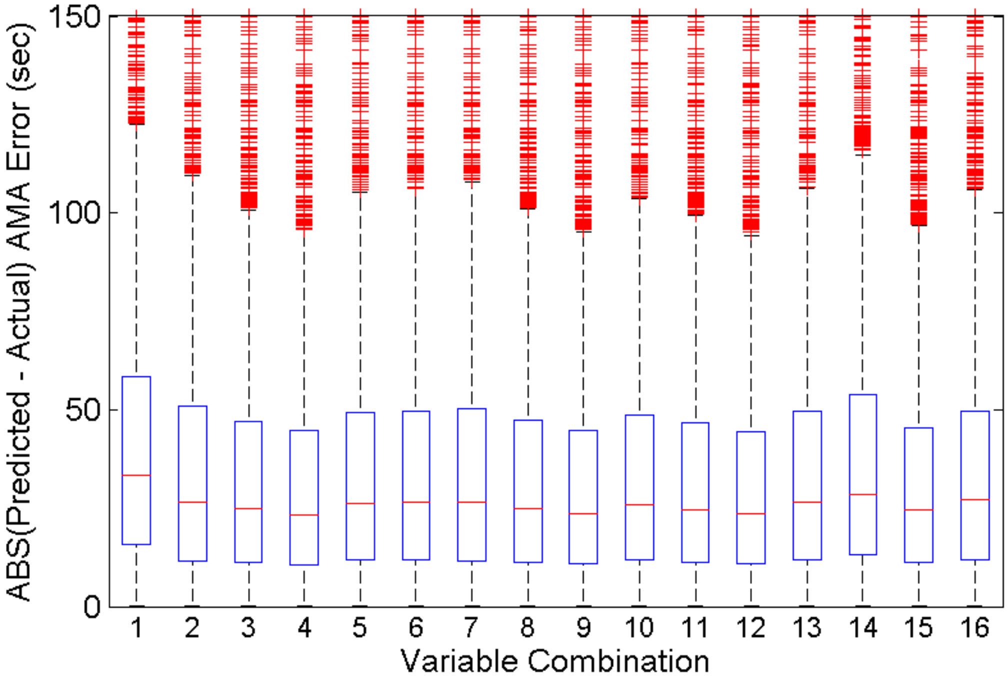
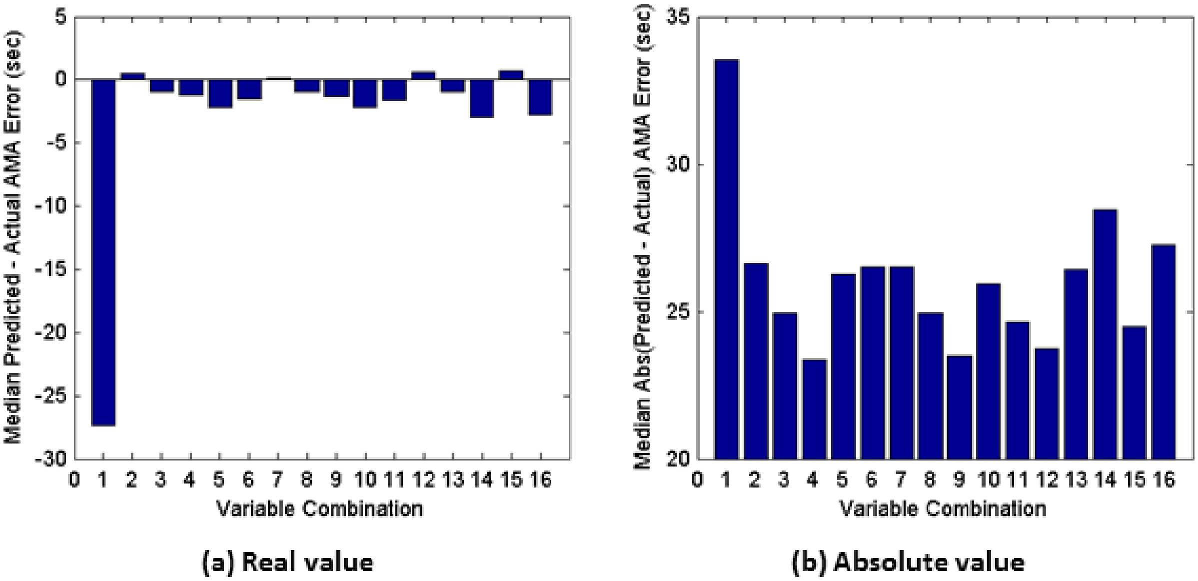


Figure 11:3 – Box plot of Absolute AMA Taxi Time Error

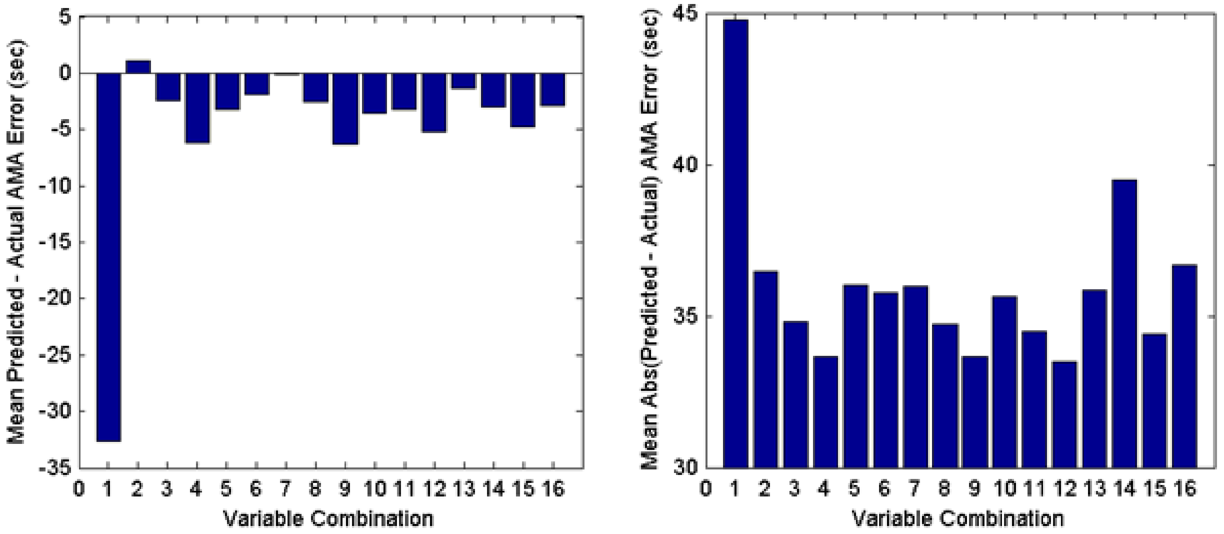
The charts in Figure 11:4 depict the real and absolute median error for each variable combination. All combinations results in a decreased value of real and absolute error when compared to the default speed of 17 knots. In terms of real median error, combination 7 (Carrier, Aircraft Type) results in the least amount of error. In terms of absolute median error, combinations 4 (Aircraft Type, Runway, Spot Group), 9 (Carrier, Aircraft Type, Runway, Spot Group), and 12 (Carrier, Runway, Spot Group) share the smallest value.



(a) Real value **(b) Absolute value**

Figure 11:4 – AMA taxi time prediction errors for 16 cases – median.

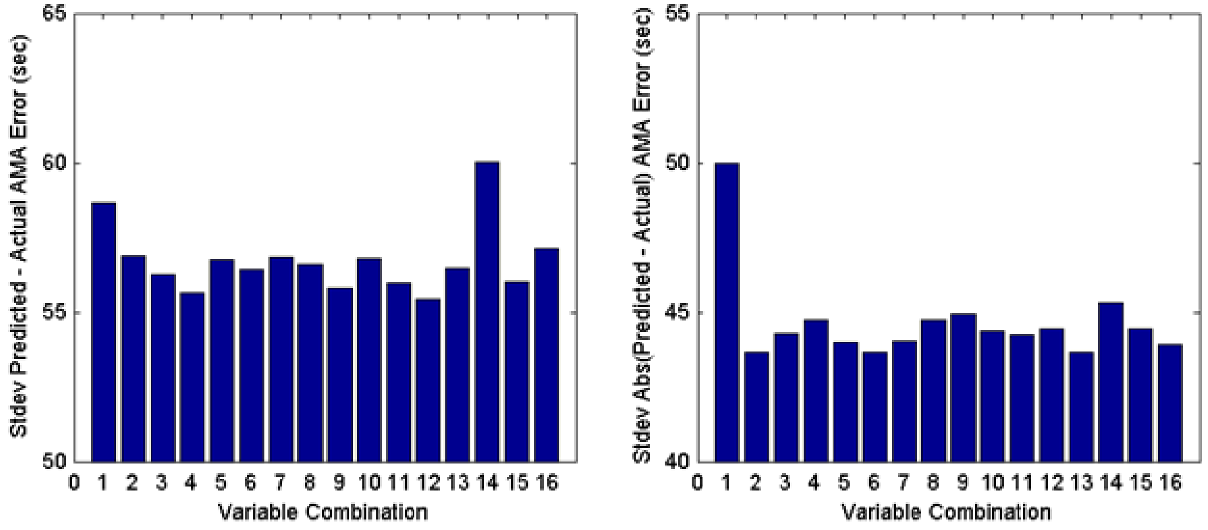
The next set of charts (Figure 11:5) shows the real and absolute mean error in AMA taxi time. Once again, combination 7 (Carrier, Aircraft Type) has the smallest actual (real) error. The smallest mean absolute error is shared between combinations 4 (Aircraft Type, Runway, Spot Group), 9 (Carrier, Aircraft Type, Runway, Spot Group), and 12 (Carrier, Runway, Spot Group).



(a) Real value **(b) Absolute value**

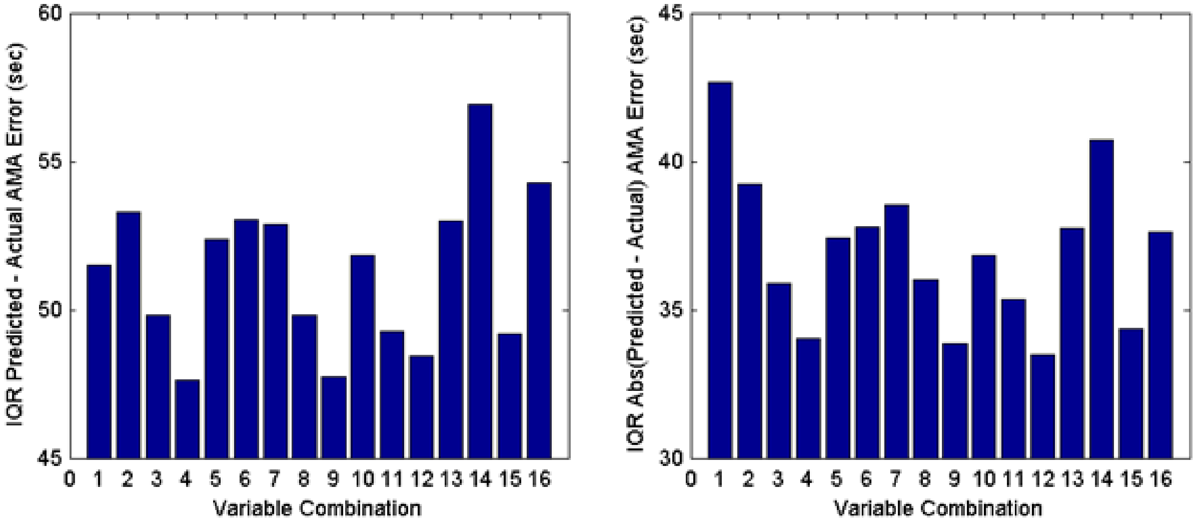
Figure 11:5 – AMA taxi time prediction errors for 16 cases – mean.

The “tightness” of the errors is shown in the next two figures in terms of standard deviation and inter-quartile range. Figure 11:6 shows the real and absolute standard deviation of the errors, while Figure 11:7 shows the interquartile range of the real and absolute errors. Excluding combination 14 (Runway), all other combinations show similar values for standard deviation. The smallest inter-quartile range values are achieved using combinations 4 (Aircraft Type, Runway, Spot Group), 9 (Carrier, Aircraft Type, Runway, Spot Group), or 12 (Carrier, Runway, Spot Group).



(a) Real value **(b) Absolute value**

Figure 11:6 – AMA taxi time prediction errors for 16 cases (standard deviation).



(a) Real value **(b) Absolute value**

Figure 11:7 – AMA taxi time prediction errors for 16 cases (interquartile range).

11.6 Recommendations based on multivariate regression analysis

The variable combinations that exhibit the overall smallest amount of error and “tightness” are

- combination 4: Aircraft Type, Runway, Spot Group
- combination 9: Carrier, Aircraft Type, Runway, Spot Group
- combination 12: Carrier, Runway, Spot Group

With regards to implementation, either combination 4 or combination 12 would be the least difficult to accomplish. Combination 9 would add complexity to the departure_taxi_speed_decision tree without adding any more reduction in error.

11.7 Implementation challenges

The recommended three-variable solution led to large adaptation decision trees, which negatively impacted SDSS processing speed. Consequently, the team elected to use a less-demanding two-variable solution. Aircraft type and carrier were selected as the variables.

Implementation of the new decision tree involved additional design decisions for specific variables. For example, a B350 aircraft was found to be used only 4 times throughout the original multivariate analysis, each with a different carrier. Instead of splitting the decision tree by carrier, in this case the mean value between the carriers was used in order to avoid creating a larger file size that could potentially decrease SDSS system performance. This methodology was used for various other aircraft types when it was clear that a single value would be fine.

11.8 Post-implementation analysis

This follow-up analysis documented the impact of the new AMA departure taxi speed logic implemented in SDSS. The analysis examined the accuracy of SDSS AMA taxi time calculations during the first three weeks (11/5/2012 to 11/27/2012) of the PDRC Block 2 operational evaluation. The analysis also examined the accuracy of OFF time predictions from the PDRC Block 1 operational evaluation (4/30/2012 – 7/26/2012), compared to partial results from the Block 2 operational evaluation. The OFF time error is shown as an aggregate value (median) as a function of time-to-OFF.

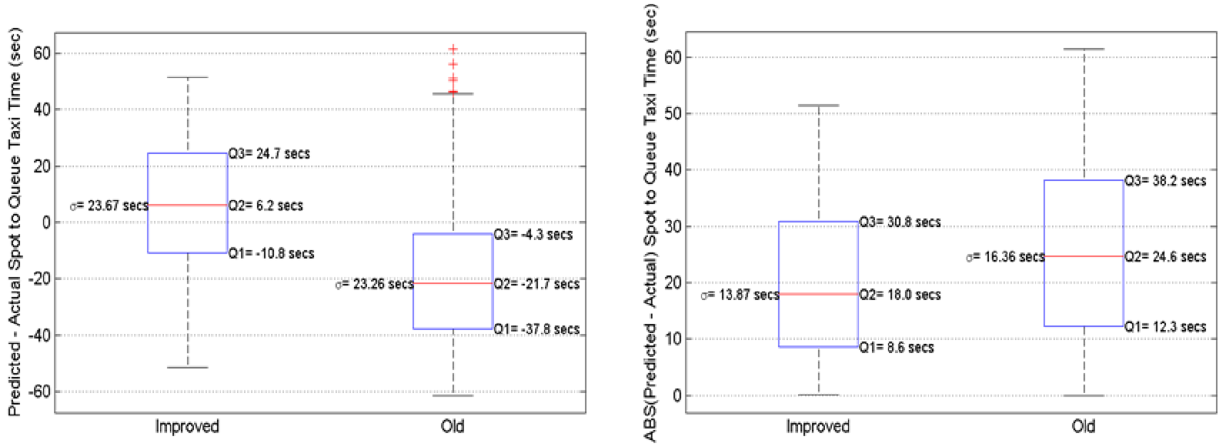
11.8.1 Spot-to-Queue Taxi Time Error

Data from 11/5/2012 to 11/27/2012 (a portion of Block 2 operational evaluation) were analyzed to find the spot-to-queue taxi time error. The actual spot-to-queue taxi time was compared to two sets of predicted values, one using the new departure_taxi_speed_decision_tree and one using the default value of 17 knots for taxi speed. The following filters were applied to the data before the plots were created:

- Actual spot crossed must not be <null>
- The predicted runway at time of spot crossing must equal the actual runway
- The predicted spot at time of spot crossing must equal the actual spot
- The flight must not have an EDCT time

After these filters were applied, the AMA taxi time error was calculated as the predicted spot-to-queue taxi time minus the actual spot-to-queue taxi time. Flights with absolute taxi time error greater than the 75th percentile of the absolute error were removed from the analysis.

Figure 11:8 shows the spot-to-queue taxi time error for data from 11/5/2012 – 11/27/2012. The “Improved” dataset used the new departure_taxi_speed_decision_tree, while the “Old” dataset used a default value of 17 knots for taxi speed. Considering first the actual or real values plotted in Figure 11:8(a), the median error shifts from –21.7 to 6.2 seconds. Predicted taxi times from the spot to the queue are now more centered around 0 seconds. The IQR and standard deviation stay about the same. The total range decreases by about 20 seconds.



(a) Real value **(b) Absolute value**

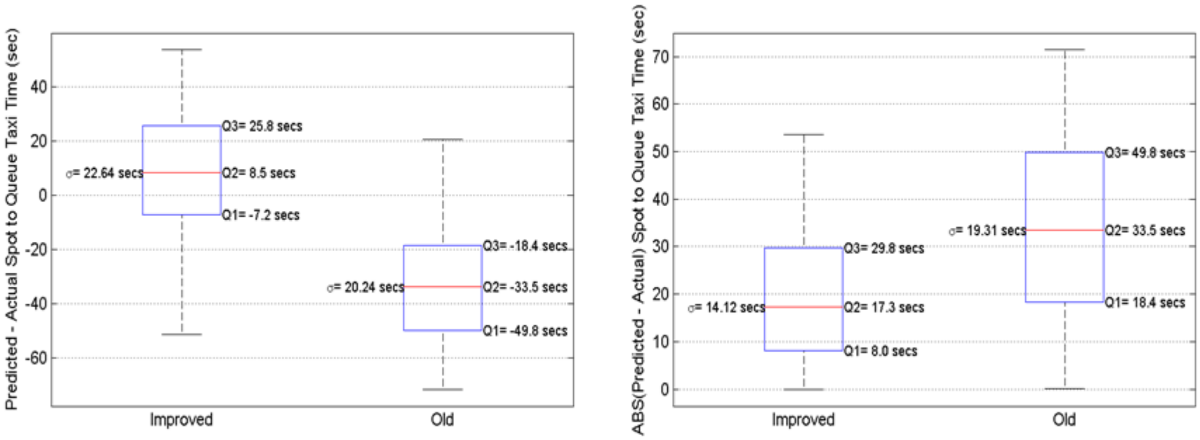
Figure 11:8 – Spot-to-queue taxi time error for all flights.

Turning attention to the comparison of absolute values shown in Figure 11:8(b) note the following differences:

- Decreased median absolute error by ~6 seconds

- Standard deviation decreased by ~3 seconds
- Inter-quartile range decreased by ~4 seconds
- Total range decreased by ~10 seconds

Figure 11:9 presents the same spot-to-queue taxi time comparisons but for American Airlines flights only. These results show even greater improvement than the overall results discussed above.

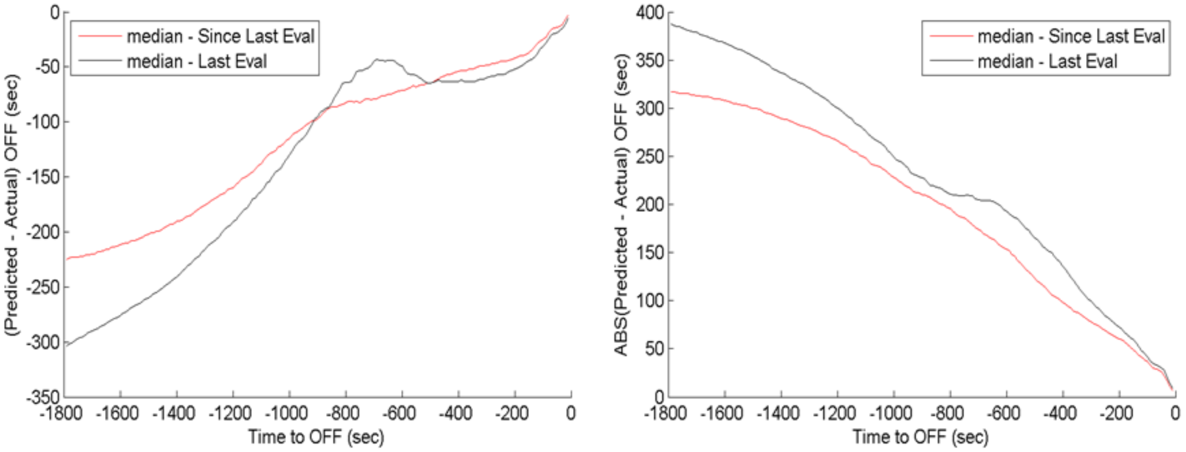


(a) Real value **(b) Absolute value**

Figure 11:9 – Spot-to-queue taxi time error for AAL flights only.

11.8.2 OFF time error

The spot-to-queue predictions are but one piece of the total prediction accuracy that could be improved. Overall, an improvement in the OFF time accuracy of all flights is desired. The following plots show the OFF time error as a function of time-to-OFF for the Block 1 operational evaluation compared to data from a portion (11/5/2012 – 11/27/2012) of the Block 2 evaluation. The errors shown are the median values at each time-to-OFFF value.



(a) Real value

(b) Absolute value

Figure 11:10 – OFF time accuracy plotted as a function of time-to-OFF for Block 1 evaluation and a portion of the Block 2 evaluation.

12 Appendix D: Block 1 operational evaluation data

This appendix contains data from the PDRC Block 1 operational evaluation. These data were used in the OFF time compliance comparison and other analyses.

Table 12:1 – Column definitions for Block 1 evaluations data.

Column label	Definition
Date (L)	Local date on which the flight departed DFW (mm/dd/yy US Central TZ)
Callsign	ATC callsign for the flight.
Type	ATC equipment type for the flight.
Dest	Destination airport.
Rwy	Actual departure runway detected from surface surveillance tracks.
CFR init	Time at which CFR scheduling was initiated (UTC hh:mm:ss)
CFR done	Time at which CFR scheduling was completed (UTC hh:mm:ss).
Release	Coordinated release time resulting from PDRC scheduling process (UTC hh:mm:ss).
OFF	Actual OFF time detected from surface surveillance tracks (UTC hh:mm:ss).
OTC?	Eligibility of flight for OFF time compliance comparison.
OTC	OFF – Release (seconds)

Table 12:2 – DFW departures scheduled with PDRC during Block 1 evaluation.

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
05/10/12	SKW5187	CRJ7	IAH	17R	15:59:10	16:08:16	16:22:35	16:20:16	NO	n/a
05/10/12	ASQ4430	E145	IAH	17R	16:23:51	16:24:39	16:29:00	16:29:32	1	32
05/10/12	AAL1560	MD83	IAH	17R	17:31:32	17:32:06	17:33:01	17:34:16	2	75
05/10/12	AAL1897	MD82	IAH	17R	20:24:43	20:25:39	20:29:23	20:41:12	NO	n/a
05/10/12	AAL1001	MD83	IAH	17R	21:18:33	21:20:20	21:51:03	21:32:22	NO	n/a
05/11/12	AAL2385	MD82	IAH	17R	12:35:26	12:35:47	12:41:11	12:39:57	3	-74
05/11/12	AAL1599	MD82	IAH	17R	14:43:47	14:44:35	14:48:32	14:49:51	4	79
05/12/12	UAL1014	B738	IAH	35L	13:29:59	13:30:34	13:35:19	13:35:12	5	-7
05/12/12	SKW5235	CRJ2	IAH	35L	14:03:52	14:04:17	14:08:12	14:09:08	6	56
05/12/12	AAL1599	MD82	IAH	35C	14:57:13	15:11:07	15:13:21	15:12:09	7	-72
05/15/12	ASQ4087	E145	IAH	35L	21:40:02	21:41:24	21:44:07	21:45:45	8	98
05/20/12	AAL2448	B738	DCA	17R	00:37:18	00:43:18	00:44:47	00:44:34	9	-13
05/22/12	AAL2025	B763	MIA	17R	13:05:47	13:05:46	13:12:35	13:17:04	NO	n/a
05/22/12	AAL1976	B752	MIA	17R	13:59:30	14:00:12	14:03:12	14:03:56	10	44

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
05/22/12	AAL1652	B738	MCO	17R	14:41:27	14:41:26	14:43:26	14:43:49	11	23
05/22/12	AAL1327	B738	MIA	17R	16:17:07	16:17:45	16:21:15	16:19:53	12	-82
05/24/12	EGF2883	E145	HOU	18L	22:47:41	22:48:28	22:53:27	22:53:30	13	3
05/31/12	EGF3254	E145	HOU	36R	21:31:27	21:31:26	21:36:18	21:36:05	14	-13
05/31/12	AAL1897	MD83	IAH	35L	22:28:59	22:32:41	22:40:16	22:40:24	15	8
05/31/12	AAL1001	MD83	IAH	35L	22:27:11	22:27:09	22:38:58	22:37:22	16	-96
05/31/12	ASQ4087	E145	IAH	35L	21:43:01	21:43:33	21:47:19	21:47:47	17	28
05/31/12	SKW5176	CRJ7	IAH	36R	19:33:08	19:35:38	19:39:37	19:40:28	18	51
06/10/12	AAL1884	MD82	ATL	17R	20:27:02	20:29:52	20:31:38	20:32:20	19	42
06/11/12	DAL1910	B752	ATL	17R	21:11:03	21:12:25	21:32:06	21:32:28	20	22
06/11/12	DAL2210	A320	ATL	17R	22:26:35	22:26:33	22:29:41	22:30:07	21	26
06/13/12	AAL1560	MD82	IAH	17R	17:33:34	17:34:55	17:37:11	17:37:42	22	31
06/13/12	SKW5173	CRJ7	IAH	17R	19:01:48	19:03:17	19:08:59	19:10:09	23	70
06/13/12	AAL1897	MD83	IAH	17R	19:34:16	19:34:54	19:39:19	19:38:30	24	-49
06/14/12	AAL2385	MD83	IAH	17C	12:11:53	12:13:54	12:14:16	12:15:03	25	47
06/14/12	AAL1001	MD83	IAH	17R	21:17:58	21:19:17	21:22:21	21:24:51	26	150
06/14/12	SKW5169	CRJ7	IAH	17R	21:45:36	21:45:55	21:51:21	21:52:39	27	78
06/14/12	AAL653	MD83	IAH	17R	23:10:55	23:12:13	23:16:37	23:16:15	28	-22
06/15/12	SKW5169	CRJ7	IAH	17R	21:55:42	21:56:14	22:00:43	22:00:38	29	-5
06/15/12	AAL1001	MD83	IAH	17R	22:27:31	22:27:54	22:33:53	22:34:07	30	14
06/15/12	AAL653	MD83	IAH	17R	23:22:40	23:22:36	23:26:27	23:26:15	31	-12
06/16/12	UAL1407	B739	IAH	17R	11:38:29	11:40:02	11:43:38	11:43:46	32	8
06/16/12	AAL2385	MD83	IAH	17C	12:01:42	12:02:05	12:07:15	12:07:13	33	-2
06/16/12	AAL1001	MD83	IAH	17R	21:12:19	21:13:51	21:17:18	21:17:15	34	-3
06/16/12	SKW5169	CRJ7	IAH	17R	22:08:11	22:09:39	22:15:58	22:16:16	35	18
06/16/12	AAL653	MD83	IAH	17R	23:09:47	23:10:38	23:15:25	23:15:11	36	-14
06/18/12	AAL2385	MD83	IAH	17C	12:00:38	12:03:03	12:06:33	12:07:17	37	44
06/18/12	AAL1599	MD82	IAH	17R	14:43:15	14:47:37	14:50:39	14:49:12	38	-87
06/18/12	SKW5206	CRJ7	IAH	17R	14:46:55	14:47:20	14:53:52	14:54:18	39	26
06/18/12	ASQ4534	E145	IAH	17R	16:19:43	16:20:08	16:26:03	16:26:28	40	25
06/18/12	AAL1604	MD83	IAH	17R	17:31:08	17:31:44	17:36:14	17:36:27	41	13
06/18/12	SKW5173	CRJ7	IAH	17R	18:20:54	18:21:12	18:26:01	18:26:01	42	0
06/18/12	AAL1897	MD82	IAH	17R	19:28:25	19:29:28	19:34:53	19:35:08	43	15
06/18/12	AAL1001	MD83	IAH	17R	21:14:41	21:15:30	21:21:02	21:22:44	44	102
06/18/12	SKW5169	CRJ7	IAH	17R	21:47:41	21:51:03	21:53:16	21:53:55	45	39
06/19/12	AAL1604	MD82	IAH	17R	18:37:27	18:39:21	18:44:10	18:43:20	46	-50
06/19/12	AAL653	MD83	IAH	17R	00:31:22	00:31:47	00:41:43	00:41:42	NO	n/a
06/23/12	DAL2165	A319	DTW	17R	18:09:01	18:09:01	18:15:39	18:15:35	47	-4
06/29/12	AAL1599	MD82	IAH	17R	15:07:00	15:13:00	15:13:49	15:14:49	48	60

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
06/29/12	ASQ4534	E145	IAH	17R	16:26:38	16:28:09	16:32:39	16:32:01	49	-38
07/01/12	ASQ4693	E145	IAH	17R	13:57:01	13:57:18	14:01:14	14:00:36	50	-38
07/01/12	AAL2352	MD82	ORD	17R	19:10:55	19:11:38	19:14:01	19:15:20	51	79
07/01/12	AAL2350	MD83	ORD	18L	19:10:56	19:20:45	19:20:38	19:23:00	52	142
07/01/12	ASH3772	CRJ7	ORD	18L	19:19:49	19:20:19	19:24:20	19:24:57	53	37
07/01/12	AAL2354	MD83	ORD	18L	19:26:38	19:27:06	19:31:19	19:33:07	54	108
07/01/12	AAL1001	MD82	IAH	18L	21:42:20	21:46:00	21:52:51	21:52:46	55	-5
07/01/12	AAL848	MD83	ATL	17R	23:09:40	23:10:51	23:14:48	23:14:46	56	-2
07/01/12	DAL1810	MD88	ATL	17R	23:33:32	23:33:59	23:39:21	23:40:00	57	39
07/01/12	NKS948	A320	ORD	17R	00:25:56	00:27:37	00:31:45	00:34:21	NO	n/a
07/01/12	AAL2374	MD82	ORD	18L	01:23:50	01:24:14	01:25:49	01:26:22	58	33
07/07/12	ASQ4376	E145	IAH	17R	18:14:11	18:15:03	18:19:15	18:19:58	59	43
07/07/12	AAL1897	MD82	IAH	17R	19:31:37	19:32:30	19:38:14	19:38:27	60	13
07/07/12	SKW5188	CRJ7	IAH	17R	19:38:55	19:39:18	19:44:33	19:45:49	61	76
07/08/12	ASQ4698	E145	IAH	17R	14:10:45	14:25:17	14:25:55	14:27:58	62	123
07/08/12	ASQ4707	E145	IAH	17R	18:09:05	18:09:38	18:14:24	18:14:47	63	23
07/08/12	AAL1604	MD82	IAH	17R	18:21:32	18:21:55	18:25:25	18:26:25	64	60
07/08/12	TCF3514	E170	ORD	17R	21:40:55	21:42:48	21:46:55	21:47:37	65	42
07/08/12	AAL2362	MD83	ORD	17R	21:47:41	21:49:50	21:59:05	21:57:32	66	-93
07/08/12	AAL1001	MD83	IAH	18L	23:03:29	23:07:15	23:11:25	23:11:21	67	-4
07/10/12	SKW5195	CRJ7	IAH	35L	16:49:31	16:51:37	16:55:25	16:54:14	68	-71
07/10/12	AAL1604	MD83	IAH	35L	17:45:10	17:45:57	17:55:40	17:55:58	69	18
07/10/12	ASQ4222	E145	IAH	35L	20:22:32	20:22:56	20:31:20	20:29:57	NO	n/a
07/10/12	AAL1001	MD83	IAH	35L	21:19:59	21:20:58	21:27:21	21:28:50	70	89
07/10/12	DAL2210	MD90	ATL	35L	22:17:49	22:20:28	22:22:46	22:25:40	NO	n/a
07/11/12	EGF3215	E145	HOU	35L	15:48:48	15:49:47	15:52:56	15:52:55	71	-1
07/11/12	SKW5195	CRJ7	IAH	35L	18:08:32	18:08:55	18:18:40	18:12:52	NO	n/a
07/11/12	AAL1604	MD83	IAH	35L	19:03:04	19:04:19	19:09:47	19:09:52	NO	n/a
07/11/12	AAL1897	MD82	IAH	35L	19:48:19	19:48:49	19:58:15	19:56:46	72	-89
07/11/12	AAL1001	MD82	IAH	35L	21:14:07	21:14:40	21:24:18	21:22:09	73	-129
07/11/12	AAL653	MD83	IAH	35L	23:14:08	23:14:44	23:25:09	23:24:35	74	-34
07/11/12	ASQ4211	E145	IAH	35L	01:30:15	01:32:01	01:34:43	01:36:25	75	102
07/12/12	EGF3219	E135	HOU	35L	14:47:01	14:48:08	14:51:22	14:52:57	76	95
07/12/12	EGF2855	E145	HOU	35L	18:15:06	18:15:46	18:22:07	18:20:50	77	-77
07/12/12	ASQ4607	E145	IAH	35L	18:44:59	18:47:10	18:58:17	18:56:56	NO	n/a
07/12/12	AAL1897	MD82	IAH	35L	19:29:20	19:30:19	19:34:07	19:34:45	78	38
07/12/12	EGF3208	E145	HOU	18L	20:04:02	20:04:38	20:05:33	20:07:11	79	98
07/12/12	EGF3254	E145	HOU	18L	21:43:35	21:44:29	21:47:15	21:48:38	80	83
07/12/12	AAL1001	MD83	IAH	17R	21:45:40	21:46:42	21:53:12	21:52:31	81	-41

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
07/13/12	AAL2385	MD83	IAH	17R	12:05:34	12:05:55	12:09:59	12:10:21	82	22
07/13/12	AAL1897	MD82	IAH	17R	21:05:23	21:05:56	21:09:35	21:10:22	NO	n/a
07/13/12	DAL2010	B752	ATL	17R	21:10:19	21:11:08	21:15:09	21:17:27	83	138
07/13/12	AAL653	MD83	IAH	17R	23:13:33	23:17:47	23:22:28	23:23:48	84	80
07/15/12	ASQ4239	E45X	IAH	17R	16:26:42	16:28:19	16:34:25	16:35:01	85	36
07/15/12	ASQ4209	E145	IAH	17R	18:29:52	18:30:43	18:37:25	18:37:16	86	-9
07/15/12	AAL1604	MD82	IAH	17R	18:42:37	18:43:08	18:50:23	18:51:16	87	53
07/15/12	DAL1675	MD88	IAH	17R	19:23:49	19:24:51	19:43:47	19:41:17	88	-150
07/15/12	AAL1897	MD82	IAH	17R	19:32:43	19:33:10	19:44:08	19:46:22	89	134
07/16/12	DAL2010	B752	ATL	17R	22:16:44	22:18:40	22:25:35	22:24:35	NO	n/a
07/16/12	EGF3254	E145	HOU	17R	22:37:18	22:40:27	22:44:13	22:44:46	90	33
07/16/12	EGF2883	E145	HOU	17R	23:22:30	23:24:16	23:29:35	23:28:15	91	-80
07/18/12	AAL1897	MD82	IAH	17R	19:28:39	19:31:04	19:36:45	19:38:31	92	106
07/18/12	ASQ4682	E145	IAH	17R	19:28:08	19:31:16	19:38:04	19:40:41	93	157
07/18/12	AAL1001	MD83	IAH	17R	21:17:06	21:19:26	21:23:34	21:23:53	94	19
07/18/12	SKW5178	CRJ7	IAH	17R	21:57:59	21:58:37	22:11:55	22:10:02	95	-113
07/18/12	ASQ4211	E145	IAH	18L	00:06:39	00:07:46	00:20:13	00:18:56	96	-77
07/18/12	TCF5668	E170	IAH	17R	00:26:57	00:27:33	00:30:59	00:31:47	97	48
07/20/12	DAL1954	B752	ATL	17C	12:07:23	12:07:46	12:13:36	12:13:58	98	22
07/23/12	ASQ4376	E145	IAH	17R	19:04:17	19:04:41	19:10:39	19:12:11	99	92
07/23/12	AAL1070	MD82	PHL	17R	19:18:16	19:20:14	19:22:46	19:23:11	NO	n/a
07/23/12	AAL1897	MD82	IAH	18L	19:30:33	19:30:50	19:35:46	19:34:31	100	-75
07/23/12	AAL1156	MD82	DCA	17R	19:26:23	19:26:50	19:31:03	19:39:57	NO	n/a
07/23/12	EGF3208	E145	HOU	18L	19:59:10	19:59:26	20:05:40	20:04:38	101	-62
07/23/12	AAL1218	MD83	BWI	17R	20:00:21	20:00:47	20:16:35	20:18:19	NO	n/a
07/23/12	ASQ4682	E145	IAH	17R	20:56:28	20:56:50	21:00:57	21:00:42	NO	n/a
07/23/12	AAL1001	MD83	IAH	17R	21:33:32	21:34:05	21:39:45	21:41:26	102	101
07/23/12	SKW5178	CRJ7	IAH	17R	21:58:52	21:59:25	22:04:31	22:05:32	103	61

Table 12:3 – PDRC Block 1 flight counts by date and destination.

Date	Destination Airport										Total
	ATL	BWI	DCA	DTW	HOU	IAH	MCO	MIA	ORD	PHL	
05/10/12						5					5
05/11/12						2					2
05/12/12						3					3
05/15/12						1					1
05/20/12			1								1
05/22/12							1	3			4
05/24/12					1						1
05/31/12					1	4					5
06/10/12	1										1
06/11/12	2										2
06/13/12						3					3
06/14/12						4					4
06/15/12						3					3
06/16/12						5					5
06/18/12						9					9
06/19/12						2					2
06/23/12				1							1
06/29/12						2					2
07/01/12	2					2			6		10
07/07/12						3					3
07/08/12						4			2		6
07/10/12	1					4					5
07/11/12					1	6					7
07/12/12					4	3					7
07/13/12	1					3					4
07/15/12						5					5
07/16/12	1				2						3
07/18/12						6					6
07/20/12	1										1
07/23/12		1	1		1	5				1	9
Totals	9	1	2	1	10	84	1	3	8	1	**120**

13 Appendix E: Block 2 operational evaluation data

This appendix contains data from the PDRC Block 2 operational evaluation. These data were used in the OFF time compliance comparison and other analyses.

Table 13:1 – Column definitions for Block 2 evaluation data.

Column label	Definition
Date (L)	Local date on which the flight departed DFW (mm/dd/yy US Central TZ)
Callsign	ATC callsign for the flight.
Type	ATC equipment type for the flight.
Dest	Destination airport.
Rwy	Actual departure runway detected from surface surveillance tracks.
CFR init	Time at which CFR scheduling was initiated (UTC hh:mm:ss)
CFR done	Time at which CFR scheduling was completed (UTC hh:mm:ss).
Release	Coordinated release time resulting from PDRC scheduling process (UTC hh:mm:ss).
OFF	Actual OFF time detected from surface surveillance tracks (UTC hh:mm:ss).
OTC?	Eligibility of flight for OFF time compliance comparison.
OTC	OFF – Release (seconds)

Table 13:2 – DFW departures scheduled with PDRC during Block 2 evaluation.

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
11/08/12	EGF3219	E135	HOU	18L	14:48:05	14:48:34	14:54:34	14:53:14	1	-80
11/14/12	AAL1794	MD82	ATL	17R	16:42:13	16:42:36	16:50:09	16:49:41	2	-28
11/14/12	DAL865	MD90	ATL	17R	17:00:51	17:01:14	17:07:00	17:06:48	3	-12
11/14/12	AAL1472	MD82	ATL	17R	17:59:34	18:00:10	18:05:32	18:06:05	4	33
11/14/12	DAL1710	MD88	ATL	17R	18:28:04	18:28:36	18:42:26	18:35:10	NO	n/a
11/14/12	AAL474	MD83	ATL	17R	18:55:36	18:56:10	19:00:24	19:00:04	5	-20
11/18/12	AAL1387	MD82	AUS	18L	20:12:08	20:12:56	20:15:45	20:16:08	6	23
11/18/12	AAL1731	MD83	AUS	18L	23:25:55	23:26:21	23:34:35	23:33:47	7	-48
11/18/12	AAL1625	MD83	AUS	18L	23:35:13	23:36:02	23:42:12	23:41:50	8	-22
11/25/12	ASQ4549	E145	IAH	17R	21:54:34	21:55:40	21:59:49	21:57:51	9	-118
11/27/12	UAL1096	B738	IAH	35L	12:40:31	12:40:55	12:45:14	12:46:11	10	57
11/27/12	AAL547	MD82	IAH	35L	13:35:56	13:36:35	13:41:53	13:40:51	11	-62

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
11/27/12	NKS832	A319	IAH	35L	13:47:52	13:48:18	13:52:02	13:52:26	12	24
12/04/12	AAL1335	MD83	IAH	35L	18:58:43	19:02:09	19:02:52	19:04:20	13	88
12/04/12	EGF2855	E145	HOU	36R	19:15:51	19:17:19	19:20:15	19:22:58	NO	n/a
12/06/12	EGF3219	E135	HOU	17R	14:50:23	14:51:01	14:55:05	14:55:06	14	1
12/09/12	AAL1583	MD82	DEN	35L	22:07:08	22:07:43	22:12:19	22:13:37	15	78
12/09/12	FFT661	A319	DEN	36R	22:48:37	22:49:00	22:51:11	22:52:25	16	74
12/09/12	NKS719	A319	DEN	36R	22:55:37	22:56:26	22:58:08	22:58:32	17	24
12/09/12	UAL288	A320	DEN	36R	23:02:32	23:02:58	23:04:56	23:05:32	18	36
12/10/12	DAL1910	MD90	ATL	35L	22:27:26	22:28:38	22:35:59	22:34:08	19	-111
12/10/12	AAL2222	MD82	ATL	35L	22:48:47	22:51:32	22:57:31	22:57:03	20	-28
12/16/12	FFT137	A319	DEN	36R	15:14:47	15:15:38	15:24:58	15:22:48	21	-130
12/16/12	AAL1241	MD83	DEN	18L	16:20:23	16:20:58	16:26:39	16:25:56	22	-43
12/16/12	UAL1700	B738	IAH	17R	16:27:09	16:28:30	16:35:06	16:35:58	23	52
12/16/12	AAL547	MD82	IAH	17R	16:45:35	16:46:17	16:58:50	16:56:15	24	-155
12/16/12	AAL1729	MD82	IAH	17R	16:45:53	16:46:39	17:02:27	17:00:20	25	-127
12/16/12	UAL1718	B738	IAH	17R	16:55:51	16:56:13	17:03:08	17:04:29	26	81
12/16/12	SKW5196	CRJ7	IAH	17R	18:05:42	18:06:22	18:11:47	18:11:45	NO	n/a
12/16/12	JZA109	CRJ9	IAH	17R	18:17:51	18:18:22	18:34:11	18:33:45	27	-26
12/16/12	ASQ4606	E45X	IAH	17R	18:26:27	18:28:35	18:53:18	18:53:14	NO	n/a
12/16/12	AAL1335	MD83	IAH	17R	18:58:21	18:58:48	19:03:12	19:03:37	28	25
12/17/12	AAL1583	MD83	DEN	18L	22:19:55	22:20:21	22:22:27	22:22:45	29	18
12/17/12	RPA1125	E190	DEN	18L	22:39:30	22:39:54	22:51:38	22:48:21	30	-197
12/19/12	AAL1583	MD82	DEN	18L	22:17:01	22:18:39	22:22:19	22:22:17	31	-2
12/19/12	UAL33	B737	DEN	18L	22:55:29	22:56:11	23:05:10	23:05:57	32	47
12/19/12	NKS719	A319	DEN	18L	22:58:35	23:07:57	23:16:04	23:16:11	33	7
12/19/12	AAL1505	MD82	DEN	18L	23:18:50	23:20:02	23:24:17	23:25:58	34	101
12/20/12	AAL1381	MD82	DEN	36R	15:27:55	15:28:43	15:31:33	15:30:59	35	-34
12/23/12	NKS719	A319	DEN	36R	23:20:07	23:20:52	23:24:05	23:24:42	36	37
12/24/12	AAL1583	MD82	DEN	36R	22:34:01	22:35:52	22:39:02	22:38:32	37	-30
12/24/12	FFT125	A319	DEN	36R	22:40:51	22:41:23	22:45:09	22:45:14	38	5
12/24/12	NKS719	A319	DEN	36R	22:46:49	22:47:13	22:53:00	22:50:49	39	-131
12/28/12	NKS832	A319	IAH	35C	14:27:00	14:28:55	14:30:51	14:41:53	NO	n/a
12/28/12	AAL1729	MD82	IAH	35L	15:43:15	15:45:17	15:47:29	15:48:03	40	34
12/28/12	ASQ4193	E45X	IAH	35L	16:10:14	16:10:37	16:13:35	16:13:41	41	6
12/28/12	ASQ4655	E45X	IAH	35L	17:48:00	17:48:54	17:53:30	17:53:26	42	-4
12/28/12	ASQ5662	E45X	IAH	35L	18:00:18	18:02:12	18:02:38	18:03:31	43	53
12/31/12	UAL249	A319	DEN	18L	22:53:15	22:53:36	22:57:29	22:57:40	44	11
12/31/12	NKS719	A319	DEN	18L	22:53:18	22:57:51	22:59:00	23:00:04	NO	n/a
01/09/13	AAL1335	MD83	IAH	35L	18:53:58	18:54:34	19:00:43	19:00:18	45	-25

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
01/09/13	AAL1919	MD82	IAH	35L	20:13:26	20:14:31	20:22:48	20:21:27	46	-81
01/09/13	ASQ4476	E145	IAH	35L	20:23:34	20:25:10	20:28:43	20:28:31	47	-12
01/09/13	SKW4967	CRJ7	IAH	35L	20:50:34	20:51:17	20:56:08	20:54:48	48	-80
01/09/13	AAL463	MD82	IAH	35L	22:10:38	22:11:29	22:16:06	22:17:15	49	69
01/09/13	SKW5166	CRJ7	IAH	35L	22:14:52	22:15:48	22:21:15	22:21:49	50	34
01/10/13	AAL1729	MD82	IAH	17R	15:38:54	15:39:55	15:43:42	15:45:21	51	99
01/10/13	ASQ4674	E45X	IAH	17R	17:10:03	17:10:42	17:16:30	17:17:56	52	86
01/10/13	SKW5258	CRJ2	IAH	17R	17:48:03	17:49:04	17:54:30	17:53:23	53	-67
01/10/13	AAL1335	MD82	IAH	17R	18:53:54	18:54:25	19:01:23	19:00:56	54	-27
01/10/13	ASQ4476	E45X	IAH	17R	19:07:13	19:07:37	19:12:35	19:13:03	55	28
01/10/13	EGF3224	E145	HOU	17R	21:08:36	21:09:21	21:14:20	21:13:56	56	-24
01/13/13	AAL1729	MD82	IAH	35L	15:45:46	15:47:01	15:51:15	15:52:08	57	53
01/13/13	ASQ4258	E45X	IAH	35L	16:55:04	16:55:42	16:59:06	16:58:37	58	-29
01/13/13	AAL1335	MD82	IAH	35L	18:58:02	18:58:47	19:03:16	19:03:19	59	3
01/20/13	AAL1729	MD82	IAH	17R	15:37:15	15:40:30	15:44:45	15:41:45	NO	n/a
01/20/13	SKW5263	CRJ2	IAH	17R	17:30:33	15:40:01	15:41:01	17:31:30	NO	n/a
01/20/13	EGF3219	E135	HOU	17R	16:29:01	16:29:01	16:29:46	16:31:41	NO	n/a
01/20/13	UAL1427	B738	IAH	17R	17:30:59	17:32:56	18:21:35	17:46:22	NO	n/a
01/20/13	UAL107	B735	IAH	17R	17:30:06	17:34:26	17:44:29	17:44:26	60	-3
01/20/13	SKW4966	CRJ7	IAH	17R	17:48:10	17:49:40	17:53:00	17:53:13	NO	n/a
01/21/13	EGF3298	E145	HOU	36R	12:22:35	12:24:59	12:24:04	12:26:25	NO	n/a
01/21/13	UAL531	A319	IAH	35L	12:33:41	12:34:08	12:37:58	12:39:48	NO	n/a
01/24/13	AAL547	MD82	IAH	17R	13:01:48	13:02:08	13:03:54	13:04:01	61	7
02/01/13	NKS719	A319	DEN	18L	22:56:23	22:57:42	22:59:58	23:00:11	62	13
02/01/13	UAL617	A320	DEN	18L	22:58:12	22:58:11	23:03:21	23:03:19	63	-2
02/01/13	AAL1505	MD82	DEN	18L	23:33:46	23:33:48	23:39:30	23:39:47	64	17
02/05/13	EGF3224	E135	HOU	17R	21:25:08	21:25:56	21:30:00	21:30:43	65	43
02/05/13	EGF3448	E145	HOU	17R	22:31:42	22:32:24	22:37:03	22:37:27	66	24
02/06/13	EGF3219	E135	HOU	17R	14:53:05	14:53:57	15:02:11	15:00:18	67	-113
02/06/13	ASQ4453	E145	IAH	17R	17:04:13	17:04:12	17:22:34	17:22:10	NO	n/a
02/06/13	EGF3214	E145	HOU	17R	17:51:20	17:51:40	18:05:44	18:01:18	NO	n/a
02/06/13	SKW5248	CRJ2	IAH	17R	17:56:02	17:57:21	18:04:20	18:03:24	NO	n/a
02/06/13	AAL1335	MD82	IAH	17R	18:53:20	18:54:39	18:57:59	18:57:47	68	-12
02/06/13	AAL1919	MD83	IAH	17R	20:15:46	20:16:28	20:20:01	20:20:46	69	45
02/06/13	SKW4967	CRJ7	IAH	17R	20:27:37	20:28:12	20:36:37	20:36:42	70	5
02/06/13	AAL463	MD82	IAH	17R	22:02:28	22:03:37	22:13:15	22:13:45	71	30
02/06/13	SKW5166	CRJ7	IAH	17R	22:13:58	22:14:27	22:58:42	22:57:54	72	-48
02/11/13	AAL1335	MD82	IAH	35L	18:52:02	18:53:32	18:58:18	18:57:36	73	-42
02/11/13	AAL1919	MD83	IAH	35L	20:19:34	20:20:32	20:26:41	20:27:13	74	32

Date (L)	Callsign	Type	Dest	Rwy	CFR init	CFR done	Release	OFF	OTC?	OTC
02/11/13	SKW4967	CRJ7	IAH	17R	20:44:40	20:45:15	20:52:27	20:51:49	75	-38
02/11/13	AAL463	MD82	IAH	17R	22:04:06	22:04:21	22:18:10	22:14:36	NO	n/a
02/11/13	SKW5166	CRJ7	IAH	17R	22:19:55	22:20:50	22:39:35	22:35:04	NO	n/a
02/18/13	AAL1335	MD82	IAH	17R	18:56:46	18:57:13	19:05:25	19:03:05	76	-140
02/18/13	SKW5165	CRJ7	IAH	17R	19:13:24	19:15:20	19:18:56	19:19:08	NO	n/a
02/18/13	EGF3224	E145	HOU	35L	21:15:45	21:16:19	21:18:49	21:20:03	77	74
02/18/13	ASQ2519	CRJ2	HOU	35L	22:38:40	22:38:40	22:39:24	22:41:57	NO	n/a
02/18/13	SKW5201	CRJ7	IAH	35L	22:40:53	22:42:10	23:07:15	23:06:06	78	-69
02/18/13	SKW5166	CRJ7	IAH	35L	22:40:59	22:46:57	23:13:28	23:12:10	79	-78
02/18/13	AAL463	MD82	IAH	35L	23:11:18	23:11:57	23:25:58	23:24:10	80	-108
02/18/13	AAL635	MD82	IAH	35L	00:46:00	00:46:47	00:50:56	00:51:47	81	51
02/18/13	ASQ2509	CRJ2	HOU	35L	00:47:23	00:47:23	00:53:48	00:52:56	NO	n/a
02/19/13	SKW5166	CRJ7	IAH	17R	21:56:24	21:57:36	22:02:21	22:01:29	82	-52
02/19/13	AAL463	MD83	IAH	17R	22:05:12	22:05:28	22:08:14	22:09:21	83	67
02/20/13	AAL635	MD82	IAH	17R	00:03:12	00:05:36	00:10:04	00:10:25	NO	n/a
02/20/13	ASQ2540	CRJ2	HOU	17R	00:12:10	00:12:56	00:21:38	00:20:26	84	-72
02/20/13	ASQ2509	CRJ2	HOU	17R	00:21:26	00:21:47	00:27:01	00:25:52	85	-69
02/20/13	SKW5172	CRJ7	IAH	17R	01:38:58	01:40:11	01:44:52	01:44:06	86	-46
02/20/13	NKS116	A319	IAH	17R	01:50:38	01:52:03	01:57:31	01:55:40	87	-111
02/21/13	AAL1335	MD82	IAH	35L	19:32:30	19:33:42	19:37:29	19:37:53	88	24
02/21/13	N769M	WW24	HOU	35L	20:49:16	20:49:39	20:54:47	20:55:41	89	54
02/21/13	SKW5201	CRJ7	IAH	35L	21:10:01	21:10:37	21:16:02	21:16:51	90	49
02/21/13	ASQ2519	CRJ2	HOU	35L	21:48:14	21:48:41	21:53:48	21:54:46	91	58
02/21/13	SKW5165	CRJ7	IAH	35L	21:47:23	21:48:05	21:52:18	21:53:09	92	51
02/21/13	SKW5166	CRJ7	IAH	35L	22:18:15	22:18:37	22:36:40	22:36:05	93	-35
02/21/13	AAL1919	MD83	IAH	35L	22:48:20	22:48:42	22:56:12	22:55:31	94	-41
02/21/13	NKS948	A320	ORD	35L	23:52:54	23:53:40	23:56:18	23:57:12	95	54
02/21/13	ASQ2540	CRJ2	HOU	35L	00:17:21	00:18:03	00:34:05	00:29:35	NO	n/a

Table 13:3 – PDRC Block 2 flight counts by date and destination.

Date	Destination Airport						Total
	ATL	AUS	DEN	HOU	IAH	ORD	
11/08/12				1			1
11/14/12	5						5
11/18/12		3					3
11/25/12					1		1
11/27/12					3		3
12/04/12				1	1		2
12/06/12				1			1
12/09/12			4				4
12/10/12	2						2
12/16/12			2		8		10
12/17/12			2				2
12/19/12			4				4
12/20/12			1				1
12/23/12			1				1
12/24/12			3				3
12/28/12					5		5
12/31/12			2				2
01/09/13					6		6
01/10/13				1	5		6
01/13/13					3		3
01/20/13				1	5		6
01/21/13				1	1		2
01/24/13					1		1
02/01/13			3				3
02/05/13				2			2
02/06/13				2	7		9
02/11/13					5		5
02/18/13				3	6		9
02/19/13					2		2
02/20/13				2	3		5
02/21/13				3	5	1	9
Total	7	3	22	18	67	1	**118**

14 Appendix F: Baseline data

This appendix contains the Baseline data set used to compute OFF Time Compliance comparison statistics and histograms. These data were gathered from ZFW operational TMA/EDC recordings beginning in November 2010 and running through October 2011. The initial set consisted of 451 DFW departures that were tactically scheduled with the operational TMA/EDC system. The data have been culled as described below:

Table 14:1 – Baseline data culling summary.

Count	Culling actions
451	Initial set of DFW tactical departures scheduled with TMA/EDC
399	Cull 52 that were also subject to EDCT times
379	Cull 20 with insufficient surface data for OFF time detection
371	Cull 8 with questionable times for TMA/EDC scheduling actions relative to actual OFF
342	Cull 29 with OTC < -293 or OTC > 388 (i.e., 1.5 x IQR outliers)

The last two rounds of culling summarized in Table 14:1 were to account for the absence of research observers during Baseline operations.

Table 14:2 – Column definitions for Baseline data.

Column label	Definition
Date (L)	Local date on which the flight departed DFW (mm/dd/yy US Central TZ)
Callsign	ATC callsign for the flight.
Type	ATC equipment type for the flight.
Dest	Destination airport.
Rwy	Actual departure runway detected from surface surveillance tracks.
CFR done	Time at which CFR scheduling was completed (UTC hh:mm:ss).
Release	Coordinated release time resulting from EDC scheduling process (UTC hh:mm:ss).
OFF	Actual OFF time detected from surface surveillance tracks (UTC hh:mm:ss).
OTC?	Eligibility of flight for OFF time compliance comparison.
OTC	OFF – Release (seconds)

Table 14:3 – DFW departures scheduled with TMA/EDC during Baseline period.

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
11/10/10	AAL1599	B738	IAH	17R	16:54:18	17:01:22	17:04:04	1	162
11/10/10	CHQ5873	EMBJ	IAH	17R	17:04:34	17:11:10	17:11:15	2	5
11/11/10	AAL1098	MD8	IAH	17R	18:37:05	18:40:43	18:39:58	3	-45
11/11/10	BTA2957	EMBJ	IAH	17R	19:18:53	19:23:00	19:25:03	4	123
11/11/10	AAL1897	MD8	IAH	17R	20:26:03	20:32:51	20:32:27	5	-24
11/11/10	COA807	B738	IAH	17R	21:39:38	21:47:40	21:46:35	6	-65
11/13/10	BTA2941	EMBJ	IAH	35L	16:37:33	16:43:00	16:45:43	7	163
11/13/10	CHQ5805	EMBJ	IAH	36R	19:12:19	19:20:13	19:19:38	8	-35
11/14/10	BTA2164	EMBJ	IAH	17R	01:20:14	01:25:32	01:26:03	9	31
11/15/10	FFT557	EA32	DEN	18L	12:35:10	12:35:06	12:37:04	10	118
11/15/10	AAL393	B738	DEN	18L	12:40:57	12:45:00	12:50:03	11	303
11/15/10	UAL315	EA32	DEN	18L	15:29:27	15:33:14	15:33:12	12	-2
11/15/10	AAL1383	MD8	DEN	18L	15:44:50	15:47:36	15:47:12	13	-24
11/16/10	MES3234	CRJ	MEM	35L	12:14:24	12:16:00	12:16:15	14	15
11/18/10	AWE583	B73S	PHX	36R	14:33:08	14:36:21	14:34:51	15	-90
11/19/10	EGF3254	EMBJ	HOU	18L	22:52:23	22:57:00	22:56:24	16	-36
11/24/10	AAL1695	B738	PHX	18L	14:34:03	14:34:02	14:36:08	17	126
11/29/10	MES3234	CRJ	MEM	17R	12:14:26	12:20:48	12:21:07	18	19
11/29/10	BTA2047	EMBJ	IAH	35L	22:29:40	22:35:00	22:34:49	19	-11
11/29/10	COA714	B738	IAH	35L	01:13:33	01:21:21	01:22:09	20	48
11/30/10	MES3234	CRJ	MEM	35L	12:20:22	12:25:00	12:24:59	21	-1
12/01/10	CHQ5873	EMBJ	IAH	17R	17:09:43	17:18:00	17:19:50	22	110
12/02/10	DAL2264	EA32	MEM	17R	12:01:50	12:07:00	12:09:10	23	130
12/03/10	EGF2855	EMBJ	HOU	18L	19:14:38	19:17:00	19:18:46	24	106
12/07/10	EGF3219	EMBJ	HOU	18L	14:44:41	14:44:36	14:46:58	25	142
12/15/10	EGF3254	EMBJ	HOU	17R	23:50:40	23:52:00	23:54:01	26	121
12/15/10	EGF2883	EMBJ	HOU	17R	00:08:06	00:10:00	00:12:08	27	128
12/24/10	COM674	CRJ	MEM	17R	12:27:48	12:32:00	12:34:58	28	178
12/24/10	FDX472	DC10	MEM	17R	13:08:20	13:16:00	13:15:41	29	-19
12/29/10	COA1014	B738	IAH	17R	14:23:09	14:33:18	14:32:10	30	-68
12/29/10	BTA3091	EMBJ	IAH	17R	23:30:14	23:37:44	23:36:23	31	-81

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
12/29/10	EGF2883	EMBJ	HOU	18L	00:04:44	00:05:00	00:06:17	32	77
12/29/10	AAL545	MD8	IAH	17R	00:40:53	00:46:00	00:46:46	33	46
12/30/10	AWE545	EA32	PHX	18L	00:36:10	00:40:00	00:39:04	34	-56
01/03/11	BTA2949	EMBJ	IAH	17R	01:11:32	01:15:00	01:16:05	35	65
01/09/11	COA1014	B73V	IAH	17R	13:08:13	13:14:39	13:11:43	36	-176
01/09/11	AAL2385	MD8	IAH	17R	13:55:39	14:02:00	13:59:45	37	-135
01/16/11	AAL1695	B738	PHX	36R	14:16:54	14:27:30	14:26:13	38	-77
01/16/11	AWE583	B73S	PHX	36R	14:19:29	14:33:32	14:33:59	39	27
01/18/11	SKW1116	CRJ	IAH	35L	19:11:21	19:17:56	19:17:06	40	-50
01/18/11	EGF3254	EMBJ	HOU	36R	22:55:52	23:05:52	23:04:07	41	-105
01/18/11	EGF2883	EMBJ	HOU	35L	00:05:29	00:10:00	00:12:29	42	149
01/25/11	COM674	CRJ	MEM	35L	12:11:43	12:16:00	12:15:31	43	-29
01/27/11	AAL2385	MD8	IAH	35L	13:09:06	13:15:00	13:17:01	44	121
01/27/11	EGF3254	EMBJ	HOU	35L	23:45:53	23:49:00	23:49:53	45	53
01/27/11	EGF2883	EMBJ	HOU	36R	00:05:09	00:10:00	00:09:37	46	-23
01/30/11	BTA2725	EMBJ	IAH	35L	17:53:58	17:58:00	17:58:04	47	4
01/30/11	AAL808	MD8	IAH	35L	18:08:33	18:12:00	18:11:54	48	-6
01/30/11	BTA2957	EMBJ	IAH	35L	19:07:04	19:11:42	19:11:11	49	-31
01/30/11	AAL1034	MD8	IAH	35L	20:53:55	21:00:00	21:01:25	50	85
01/30/11	CHQ5833	EMBJ	IAH	35L	21:00:20	21:05:00	21:08:02	51	182
01/30/11	AAL545	MD8	IAH	35L	00:11:11	00:16:00	00:17:30	52	90
01/31/11	AAL393	MD8	DEN	36R	12:48:40	12:55:00	12:53:02	53	-118
01/31/11	AAL2385	MD8	IAH	35L	13:36:17	13:44:22	13:44:20	54	-2
02/08/11	FFT127	EA32	DEN	18L	12:52:29	12:59:00	12:57:05	55	-115
02/08/11	EGF3254	EMBJ	HOU	18L	22:57:29	23:01:00	23:02:35	56	95
02/11/11	COM674	CRJ	MEM	17R	12:42:27	12:46:00	12:51:27	57	327
02/13/11	BTA3091	EMBJ	IAH	17R	22:46:48	22:56:23	22:52:38	58	-225
02/15/11	BTA3091	EMBJ	IAH	17R	22:44:36	22:51:26	22:53:13	59	107
02/15/11	EGF3254	EMBJ	HOU	17R	22:57:59	23:00:00	23:03:15	60	195
02/17/11	EGF2855	EMBJ	HOU	18L	19:43:19	19:48:00	19:50:27	61	147
02/17/11	EGF3254	EMBJ	HOU	18L	22:57:11	23:01:00	23:00:14	62	-46
02/17/11	EGF2883	EMBJ	HOU	18L	00:06:09	00:15:34	00:16:01	63	27

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
02/18/11	EGF3215	EMBJ	HOU	18L	16:40:05	16:44:00	16:45:46	64	106
02/18/11	EGF2855	EMBJ	HOU	18L	19:21:37	19:24:10	19:24:43	65	33
02/23/11	EGF3254	EMBJ	HOU	17R	23:18:42	23:22:00	23:24:18	66	138
02/24/11	CHQ5903	EMBJ	IAH	35L	22:28:49	22:32:00	22:32:50	67	50
02/26/11	AWE583	B73S	PHX	18L	14:22:33	14:32:00	14:30:59	68	-61
02/27/11	EGF3254	EMBJ	HOU	18L	22:53:45	22:59:00	22:58:47	69	-13
02/28/11	AAL2385	MD8	IAH	35L	13:08:46	13:16:00	13:15:30	70	-30
02/28/11	EGF2883	EMBJ	HOU	36R	00:24:51	00:30:00	00:31:51	71	111
03/03/11	EGF3298	EMBJ	HOU	17R	14:39:44	14:48:33	14:48:14	72	-19
03/03/11	EGF3219	EMBJ	HOU	17R	14:41:42	14:53:58	14:52:39	73	-79
03/07/11	EJA938	C750	HOU	17R	23:07:52	23:14:00	23:14:05	74	5
03/07/11	EGF3254	EMBJ	HOU	17R	23:22:34	23:28:00	23:30:52	75	172
03/09/11	FFT127	EA32	DEN	36R	12:48:36	12:55:00	12:54:47	76	-13
03/13/11	EGF2855	EMBJ	HOU	18L	18:19:42	18:23:00	18:22:33	77	-27
03/14/11	COM620	CRJ	MEM	35L	11:12:20	11:12:46	11:16:14	78	208
03/14/11	COA214	B73V	IAH	36R	15:19:31	15:23:00	15:22:34	79	-26
03/14/11	AAL1599	MD8	IAH	35L	15:21:18	15:29:53	15:28:26	80	-87
03/14/11	EGF3215	EMBJ	HOU	35L	15:53:47	15:55:50	15:55:37	81	-13
03/21/11	AWE77	EA32	PHX	18L	23:43:01	23:47:00	23:47:04	82	4
03/26/11	AWE583	B73S	PHX	18R	13:24:19	13:36:13	13:33:09	83	-184
03/26/11	AAL1695	MD8	PHX	18R	13:38:07	13:44:00	13:44:03	84	3
03/26/11	OAE366	DC10	ATL	35L	20:35:28	20:48:00	20:45:54	85	-126
03/28/11	DAL2510	MD8	ATL	17R	13:23:03	13:35:00	13:34:08	86	-52
03/31/11	EJA357	C650	HOU	35L	23:26:56	23:28:00	23:30:36	87	156
04/03/11	EGF3254	EMBJ	HOU	18L	21:54:32	21:58:00	21:59:51	88	111
04/04/11	AAL1599	MD8	IAH	36R	15:45:02	15:45:00	15:49:37	89	277
04/04/11	EGF3215	EMBJ	HOU	35L	15:57:02	16:01:00	16:03:28	90	148
04/04/11	EGF3254	EMBJ	HOU	36R	22:11:33	22:16:00	22:17:57	91	117
04/04/11	EGF2883	EMBJ	HOU	36R	23:34:20	23:38:00	23:37:58	92	-2
04/05/11	CHQ5853	EMBJ	IAH	17R	16:31:09	16:38:00	16:37:50	93	-10
04/07/11	EGF2855	EMBJ	HOU	17R	18:30:19	18:36:00	18:36:16	94	16
04/07/11	EGF3254	EMBJ	HOU	18L	21:53:41	21:57:00	21:56:33	95	-27

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
04/09/11	AAL1695	MD8	PHX	18L	13:28:29	13:33:00	13:32:51	96	-9
04/09/11	AWE583	B73S	PHX	18L	13:28:57	13:54:35	13:53:18	97	-77
04/15/11	AAL2385	MD8	IAH	35L	12:10:55	12:16:00	12:18:12	98	132
04/23/11	AAL1695	MD8	PHX	18L	13:31:37	13:36:00	13:34:22	99	-98
04/23/11	AWE583	B73S	PHX	18L	13:34:00	13:43:30	13:41:55	100	-95
04/24/11	AWE714	EMBJ	PHL	17R	18:04:45	18:05:40	18:11:05	101	325
04/25/11	FDX1201	DC10	MEM	35L	04:06:48	04:17:48	04:18:02	102	14
04/25/11	FDX1365	DC10	MEM	35C	04:07:23	04:22:36	04:25:06	103	150
04/26/11	CHQ5853	EMBJ	IAH	35L	16:05:37	16:16:27	16:17:33	104	66
05/02/11	FDX1201	DC10	MEM	35C	03:01:17	03:07:00	03:08:50	105	110
05/03/11	DAL2211	B738	ATL	17R	21:04:49	21:09:00	21:09:05	106	5
05/03/11	AAL2222	B738	ATL	17R	21:10:49	21:13:00	21:13:04	107	4
05/03/11	AAL832	B738	ATL	17R	22:32:59	22:38:00	22:37:47	108	-13
05/03/11	TRS110	B738	ATL	17R	22:37:29	22:45:00	22:43:38	109	-82
05/03/11	DAL1810	MD8	ATL	17R	00:10:17	00:15:00	00:13:51	110	-69
05/12/11	CHQ5942	EMBJ	IAH	17R	16:17:19	16:33:44	16:35:22	111	98
05/12/11	AAL1560	MD8	IAH	17R	17:14:14	17:24:00	17:23:42	112	-18
05/12/11	COA469	B738	IAH	17R	17:21:14	17:25:59	17:31:03	113	304
05/12/11	EGF2883	EMBJ	HOU	17R	01:52:03	01:58:58	01:57:04	114	-114
05/13/11	TRS106	MD8	ATL	35L	19:00:19	19:06:00	19:07:45	115	105
05/13/11	AAL1074	MD8	ATL	35L	19:22:29	19:27:00	19:31:35	116	275
05/13/11	DAL2211	EA32	ATL	35L	21:02:22	21:07:12	21:07:06	117	-6
05/13/11	AAL832	B738	ATL	35L	23:21:18	23:21:04	23:23:32	118	148
05/13/11	TRS110	MD8	ATL	35L	23:25:26	23:27:02	23:27:34	119	32
05/13/11	DAL2210	B757	ATL	35L	23:40:11	23:45:00	23:45:01	120	1
05/13/11	TRS102	B738	ATL	35L	00:15:45	00:21:26	00:20:44	121	-42
05/13/11	DAL2060	MD8	ATL	35L	00:46:14	00:51:17	00:52:28	122	71
05/16/11	ASQ4987	CRJ	MEM	35L	11:25:33	11:35:47	11:35:10	123	-37
05/16/11	EGF2883	EMBJ	HOU	36R	23:07:49	23:08:00	23:09:14	124	74
05/17/11	AAL2513	MD8	DEN	18L	00:44:19	00:54:53	00:53:00	125	-113
05/24/11	AWE77	EA32	PHX	18L	23:57:10	00:04:56	00:04:09	126	-47
05/26/11	AAL2364	MD8	ORD	36R	22:03:20	22:05:00	22:05:51	127	51

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
05/26/11	SKW6751	CRJ	ORD	36R	22:15:17	22:20:00	22:20:41	128	41
05/26/11	ASH3763	CRJ	ORD	36R	23:03:06	23:07:00	23:07:19	129	19
05/30/11	EGF2883	EMBJ	HOU	18L	23:17:01	23:20:00	23:24:36	130	276
05/31/11	EGF3219	EMBJ	HOU	18L	13:48:03	13:51:00	13:52:25	131	85
06/03/11	FFT419	EA32	DEN	18L	00:43:19	00:53:00	00:50:39	132	-141
06/03/11	AAL2513	MD8	DEN	18L	01:26:46	01:34:54	01:32:49	133	-125
06/06/11	COA314	B73V	IAH	17R	21:17:15	21:23:46	21:28:04	134	258
06/06/11	EGF3254	EMBJ	HOU	17R	22:10:47	22:16:40	22:17:17	135	37
06/06/11	EGF2883	EMBJ	HOU	18L	00:03:27	00:14:50	00:14:28	136	-22
06/08/11	EGF3254	EMBJ	HOU	18L	23:01:27	23:04:00	23:04:17	137	17
06/08/11	EGF2883	EMBJ	HOU	18L	23:05:02	23:06:39	23:08:04	138	85
06/08/11	UAL583	EA32	DEN	18L	00:19:35	00:23:41	00:24:51	139	70
06/08/11	AAL2513	MD8	DEN	18L	00:40:08	00:44:02	00:44:42	140	40
06/08/11	FFT419	EA32	DEN	18L	00:40:29	00:47:05	00:48:23	141	78
06/10/11	TCF3459	EMBJ	ORD	18L	22:16:42	22:22:08	22:22:23	142	15
06/10/11	AAL2364	MD8	ORD	18L	22:01:30	22:05:00	22:05:39	143	39
06/10/11	DAL2210	EA32	ATL	17R	22:07:40	22:13:00	22:14:52	144	112
06/10/11	TRS110	MD8	ATL	17R	22:43:10	22:48:00	22:49:15	145	75
06/10/11	AAL1982	MD8	IAH	17R	23:15:37	23:20:00	23:20:41	146	41
06/11/11	DAL2210	EA32	ATL	17R	23:24:48	23:31:21	23:36:19	147	298
06/15/11	DAL910	MD8	ATL	17R	01:52:44	01:57:00	01:58:56	148	116
06/15/11	SKW6381	CRJ	ORD	18L	01:55:55	02:02:54	02:00:56	149	-118
06/15/11	AAL1332	MD8	ATL	17R	01:58:28	02:01:00	02:03:08	150	128
06/16/11	COM544	CRJ	MEM	17R	21:56:28	22:00:00	22:03:32	151	212
06/16/11	FDX1201	DC10	MEM	17C	02:45:37	02:49:38	02:49:08	152	-30
06/17/11	AAL1695	MD8	PHX	18L	13:38:08	13:39:00	13:44:47	153	347
06/17/11	AWE436	B73S	PHX	18L	13:38:26	13:41:00	13:46:45	154	345
06/17/11	AAL1074	MD8	ATL	17R	19:35:55	19:42:32	19:43:08	155	36
06/17/11	DAL2010	MD8	ATL	17R	19:36:21	19:46:22	19:47:03	156	41
06/17/11	WOA8128	MD11	ATL	17R	20:27:12	20:31:00	20:30:44	157	-16
06/17/11	AAL2162	B738	ATL	17R	20:35:56	20:38:00	20:38:16	158	16
06/17/11	DAL1910	B757	ATL	17R	20:50:02	20:54:00	21:00:05	159	365

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
06/17/11	DAL910	MD8	ATL	17R	01:20:15	01:25:07	01:26:16	160	69
06/17/11	AAL1306	MD8	ATL	17R	01:09:34	01:14:00	01:14:16	161	16
06/20/11	AAL808	MD8	DCA	17R	17:08:24	17:08:21	17:11:56	162	215
06/20/11	COA1758	B738	EWR	17R	17:34:28	17:40:00	17:42:41	163	161
06/20/11	AAL886	MD8	DCA	17R	17:48:10	17:48:08	17:51:48	164	220
06/20/11	AWE1154	EMBJ	PHL	17R	17:53:30	18:05:37	18:05:33	165	-4
06/20/11	AAL730	MD8	LGA	17R	18:48:24	18:54:00	18:54:43	166	43
06/20/11	AAL2272	MD8	PHL	17R	18:50:01	18:57:00	18:58:01	167	61
06/20/11	MES2470	CRJ	JFK	17R	18:45:10	18:50:00	18:52:35	168	155
06/20/11	AAL1250	MD8	EWR	17R	18:50:29	18:59:22	19:00:49	169	87
06/20/11	AAL688	B738	JFK	17R	19:28:57	19:34:00	19:38:56	170	296
06/20/11	AAL1156	MD8	DCA	17R	19:29:33	19:34:00	19:34:57	171	57
06/20/11	AAL1720	MD8	IAD	17R	20:08:05	20:11:00	20:13:12	172	132
06/20/11	AWE728	EA32	PHL	17R	19:56:48	19:59:00	20:02:19	173	199
06/21/11	COA540	B738	IAH	17R	16:19:33	16:34:20	16:33:54	174	-26
06/21/11	AAL1560	MD8	IAH	17R	18:09:34	18:14:00	18:12:50	175	-70
06/21/11	SKW1161	CRJ	IAH	17R	19:32:17	19:35:00	19:35:56	176	56
06/21/11	AAL1897	MD8	IAH	17R	19:50:17	20:06:44	20:04:30	177	-134
06/21/11	EGF3254	EMBJ	HOU	17R	22:06:31	22:09:00	22:09:33	178	33
06/21/11	AAL1982	MD8	IAH	17R	00:28:24	00:32:41	00:31:12	179	-89
06/22/11	COA1777	B738	IAH	17R	16:39:00	16:46:43	16:45:54	180	-49
06/22/11	BTA2725	EMBJ	IAH	17R	16:37:13	16:44:14	16:42:50	181	-84
06/22/11	AAL1560	MD8	IAH	17R	17:40:45	17:45:00	17:44:10	182	-50
06/22/11	AAL1897	MD8	IAH	17R	20:04:06	20:11:27	20:11:12	183	-15
06/22/11	SKW1161	CRJ	IAH	17R	20:41:58	20:47:00	20:47:22	184	22
06/22/11	AAL1367	MD8	IAH	17R	00:59:09	01:10:30	01:08:18	185	-132
06/23/11	COA1816	B73V	IAH	17R	12:22:15	12:25:44	12:24:59	186	-45
06/23/11	AAL2385	MD8	IAH	17R	12:47:07	12:50:00	12:51:48	187	108
06/23/11	AAL1560	MD8	IAH	17R	17:41:29	17:45:48	17:45:23	188	-25
06/23/11	SKW1161	CRJ	IAH	17R	19:54:15	20:00:00	19:58:03	189	-117
06/23/11	AAL1897	MD8	IAH	18L	19:59:25	20:01:35	20:02:03	190	28
06/27/11	TCF3480	EMBJ	ORD	18L	12:03:24	12:06:04	12:05:01	191	-63

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
06/27/11	AAL2324	MD8	ORD	18L	12:04:35	12:12:00	12:12:58	192	58
06/27/11	AAL2330	MD8	ORD	18L	13:31:45	13:37:00	13:37:29	193	29
06/28/11	AAL1897	MD8	IAH	18L	20:10:19	20:14:12	20:13:14	194	-58
06/30/11	EGF3215	EMBJ	HOU	18L	15:19:28	15:23:00	15:23:00	195	0
06/30/11	N881A	C25B	HOU	17R	15:38:52	15:39:33	15:42:09	196	156
07/05/11	DAL1910	B757	ATL	17R	21:23:17	21:32:00	21:30:57	197	-63
07/05/11	TRS102	B738	ATL	17R	00:00:00	00:05:26	00:07:05	198	99
07/07/11	AAL745	B738	DEN	18L	22:21:57	22:27:00	22:27:24	199	24
07/07/11	TCF3547	EMBJ	DEN	18L	22:12:04	22:16:00	22:15:59	200	-1
07/08/11	DAL2110	MD8	ATL	17R	18:17:23	18:23:00	18:22:08	201	-52
07/08/11	AAL1074	MD8	ATL	17R	19:39:50	19:43:03	19:45:17	202	134
07/08/11	DAL2010	MD8	ATL	17R	19:34:12	19:40:00	19:41:03	203	63
07/08/11	AAL2162	B738	ATL	17R	20:46:32	20:46:25	20:49:29	204	184
07/08/11	DAL1910	B757	ATL	17R	21:00:43	21:05:00	21:06:37	205	97
07/08/11	DAL2210	EA32	ATL	17R	22:07:20	22:11:00	22:13:43	206	163
07/08/11	TRS110	MD8	ATL	17R	22:45:32	22:50:00	22:52:31	207	151
07/12/11	EGF2883	EMBJ	HOU	18R	23:15:25	23:19:00	23:19:22	208	22
07/12/11	AAL1982	MD8	IAH	17R	23:18:26	23:22:00	23:21:34	209	-26
07/12/11	AAL1306	MD8	ATL	17R	00:32:54	00:37:50	00:38:45	210	55
07/14/11	AAL162R	B738	ATL	17R	21:07:13	21:12:20	21:12:45	211	25
07/14/11	DAL1910	B757	ATL	17R	21:03:07	21:03:05	21:09:15	212	370
07/14/11	NAO972	B767	ATL	17R	21:49:10	21:54:00	21:57:42	213	222
07/14/11	TRS110	MD8	ATL	17R	22:35:54	22:42:41	22:43:20	214	39
07/14/11	DAL1810	MD8	ATL	17R	23:27:59	23:32:00	23:30:15	215	-105
07/14/11	BTA3158	EMBJ	IAH	17R	00:20:44	00:28:06	00:28:33	216	27
07/18/11	AAL1599	MD8	IAH	17R	14:57:34	15:04:00	15:04:55	217	55
07/18/11	EGF3215	EMBJ	HOU	17R	15:15:43	15:20:00	15:19:34	218	-26
07/18/11	AAL1560	MD8	IAH	17R	17:41:36	17:47:00	17:51:43	219	283
07/18/11	AAL1897	MD8	IAH	17R	20:03:42	20:06:00	20:07:41	220	101
07/19/11	AAL1560	MD8	IAH	17R	17:55:53	18:05:17	18:02:03	221	-194
07/19/11	AAL1897	MD8	IAH	18R	20:01:26	20:05:00	20:07:43	222	163
07/19/11	AAL1982	MD8	IAH	17R	23:08:56	23:14:00	23:18:47	223	287

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
07/22/11	SKW1162	CRJ	IAH	17R	20:21:39	20:29:00	20:27:43	224	-77
07/22/11	AAL1897	MD8	IAH	17R	20:05:11	20:05:07	20:07:18	225	131
07/22/11	AAL736	MD8	LGA	17R	20:18:00	20:24:00	20:21:53	226	-127
07/22/11	COA1473	B73V	EWR	17R	20:22:00	20:29:00	20:29:43	227	43
07/22/11	AAL738	B738	LGA	17R	20:28:32	20:36:00	20:34:35	228	-85
07/25/11	SKW1162	CRJ	IAH	17R	19:28:28	19:29:02	19:32:23	229	201
07/25/11	EGF3254	EMBJ	HOU	18R	21:56:29	21:56:15	21:59:08	230	173
07/25/11	AAL982Q	MD8	IAH	17R	23:44:36	23:50:00	23:49:50	231	-10
07/25/11	BTA3158	EMBJ	IAH	17R	00:11:08	00:16:00	00:16:10	232	10
07/25/11	AAL1367	MD8	IAH	17R	00:57:02	01:02:00	01:02:48	233	48
07/26/11	AAL1560	MD8	IAH	17R	17:42:14	17:42:13	17:43:37	234	84
07/26/11	SKW1162	CRJ	IAH	17R	19:33:00	19:38:00	19:38:40	235	40
07/26/11	AAL1897	MD8	IAH	18R	19:50:08	19:57:00	19:59:01	236	121
07/26/11	AAL1982	MD8	IAH	17R	23:15:56	23:21:00	23:20:08	237	-52
07/26/11	BTA3158	EMBJ	IAH	17R	00:28:52	00:34:28	00:37:06	238	158
07/26/11	AAL2513	MD8	DEN	18R	00:22:56	00:28:08	00:28:46	239	38
07/26/11	FFT419	EA32	DEN	18R	00:36:53	00:50:40	00:49:53	240	-47
07/26/11	UAL583	EA32	DEN	18R	00:58:00	01:09:51	01:07:24	241	-147
07/28/11	AAL1599	MD8	IAH	17R	14:57:26	15:04:14	15:04:57	242	43
07/28/11	COA1749	B73V	IAH	17R	16:34:15	16:40:00	16:41:14	243	74
07/28/11	BTA2725	EMBJ	IAH	17R	16:37:10	16:46:00	16:45:28	244	-32
07/28/11	AAL1560	MD8	IAH	17R	17:49:42	17:54:00	17:56:06	245	126
07/28/11	SKW1162	CRJ	IAH	17R	19:59:05	20:04:00	20:07:07	246	187
07/28/11	AAL1897	MD8	IAH	17R	19:48:03	19:52:00	19:54:36	247	156
07/29/11	TCF3538	EMBJ	ORD	17R	11:50:44	12:06:40	12:06:49	248	9
07/29/11	AAL2324	MD8	ORD	17R	12:01:29	12:15:04	12:16:49	249	105
07/29/11	AAL2328	MD8	ORD	18R	13:10:40	13:17:00	13:16:52	250	-8
07/29/11	AAL2330	MD8	ORD	17R	13:25:30	13:30:00	13:33:06	251	186
07/29/11	BTA2725	EMBJ	IAH	17R	16:36:28	16:42:00	16:41:58	252	-2
07/29/11	EGF3254	EMBJ	HOU	17R	22:14:43	22:17:00	22:18:24	253	84
07/29/11	EGF2883	EMBJ	HOU	17R	23:10:02	23:12:00	23:16:19	254	259
07/29/11	AAL1367	MD8	IAH	17R	01:00:48	01:07:05	01:09:56	255	171

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
07/30/11	AAL2385	MD8	IAH	17R	12:23:28	12:24:37	12:26:38	256	121
08/04/11	FFT419	EA32	DEN	18R	00:37:24	00:43:00	00:44:31	257	91
08/07/11	AAL2374	MD8	ORD	17R	01:10:17	01:15:00	01:16:56	258	116
08/08/11	AAL2328	MD8	ORD	18R	13:18:34	13:28:00	13:29:07	259	67
08/08/11	AAL2330	MD8	ORD	17R	13:40:37	13:45:00	13:45:01	260	1
08/09/11	EGF3254	EMBJ	HOU	18R	21:57:50	22:03:00	22:02:50	261	-10
08/11/11	EGF3219	EMBJ	HOU	18R	13:43:42	13:49:14	13:54:21	262	307
08/11/11	FLG3954	CRJ	MEM	17R	16:45:27	16:50:00	16:49:18	263	-42
08/13/11	UAL301	EA32	ORD	18R	20:43:25	20:52:56	20:52:34	264	-22
08/17/11	TCF3542	EMBJ	DEN	18R	22:19:54	22:19:53	22:23:18	265	205
08/17/11	AAL2477	MD8	LAX	18R	01:39:10	01:44:00	01:44:16	266	16
08/17/11	AAL2489	B757	LAX	18R	02:02:53	02:02:44	02:07:11	267	267
08/18/11	EGF3298	EMBJ	HOU	18R	12:51:37	13:00:04	12:59:42	268	-22
08/18/11	EGF3215	EMBJ	HOU	18R	15:25:41	15:31:00	15:31:10	269	10
08/23/11	SKW2030	CRJ	IAH	17R	21:09:14	21:12:00	21:14:36	270	156
08/23/11	AAL1001	MD8	IAH	17R	23:05:15	23:05:00	23:08:35	271	215
08/25/11	COA1162	B73V	IAH	17C	12:16:31	12:23:49	12:23:49	272	0
08/25/11	AAL2385	MD8	IAH	18R	12:47:23	12:52:00	12:56:56	273	296
08/25/11	EGF3298	EMBJ	HOU	18R	13:03:58	13:07:00	13:07:13	274	13
08/25/11	AAL1591	MD8	IAH	17R	15:03:27	15:03:59	15:06:45	275	166
08/25/11	BTA2342	EMBJ	IAH	17R	16:21:34	16:30:48	16:29:51	276	-57
08/25/11	BTA3071	EMBJ	IAH	17R	16:34:28	16:40:00	16:39:27	277	-33
08/25/11	AAL1560	MD8	IAH	17R	17:39:29	17:42:00	17:42:35	278	35
08/28/11	AAL1591	MD8	IAH	17R	14:47:44	15:00:00	15:05:11	279	311
09/02/11	UAL370	EA32	IAD	17R	16:49:38	16:55:00	16:54:52	280	-8
09/03/11	AAL2366	MD8	ORD	36R	22:33:23	22:35:00	22:34:43	281	-17
09/05/11	DAL1910	B757	ATL	35L	20:49:58	20:54:00	20:53:32	282	-28
09/06/11	EGF3215	EMBJ	HOU	36R	15:28:16	15:32:00	15:33:24	283	84
09/15/11	ATN517	DC8S	IAH	36R	13:54:08	13:57:00	13:58:26	284	86
09/15/11	AAL1001	MD8	IAH	35L	00:38:38	00:43:00	00:44:53	285	113
09/15/11	SKW2009	CRJ	IAH	35L	00:39:03	00:43:50	00:47:21	286	211
09/16/11	AAL1591	MD8	IAH	18L	15:10:40	15:15:00	15:13:38	287	-82

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
09/18/11	AAL1560	MD8	IAH	17R	17:32:24	17:32:23	17:38:16	288	353
09/18/11	EGF2855	EMBJ	HOU	18L	18:16:08	18:19:00	18:19:17	289	17
09/18/11	AAL1897	MD8	IAH	17R	19:55:59	20:01:03	19:59:50	290	-73
09/18/11	SKW5839	CRJ	IAH	17R	20:17:20	20:29:27	20:27:39	291	-108
09/18/11	BTA1758	EMBJ	IAH	17R	21:46:58	21:53:00	21:52:19	292	-41
09/18/11	SKW2045	CRJ	IAH	17R	21:56:55	22:05:33	22:06:49	293	76
09/18/11	SKW2054	CRJ	IAH	17R	22:55:14	23:01:00	23:02:29	294	89
09/18/11	AAL1001	MD8	IAH	17R	23:24:04	23:24:01	23:29:37	295	336
09/18/11	EGF2883	EMBJ	HOU	18L	23:10:10	23:10:03	23:11:33	296	90
09/19/11	COA1032	B73V	IAH	35L	11:56:57	12:01:00	12:03:05	297	125
09/19/11	AAL2385	MD8	IAH	35L	12:13:30	12:23:44	12:22:35	298	-69
09/21/11	BTA2342	EMBJ	IAH	17R	16:14:30	16:21:00	16:21:22	299	22
09/21/11	SKW461L	CRJ	LAX	18L	01:29:18	01:34:00	01:35:31	300	91
09/22/11	AWE436	B73S	PHX	36R	13:35:53	13:40:00	13:39:39	301	-21
09/22/11	AAL1695	MD8	PHX	36R	13:56:06	13:59:00	14:01:48	302	168
09/22/11	EGF3254	EMBJ	HOU	35L	21:58:14	21:58:11	22:00:45	303	154
09/25/11	DAL2210	B757	ATL	35L	22:31:33	22:36:00	22:36:10	304	10
09/25/11	DAL1810	MD8	ATL	35L	23:28:25	23:33:00	23:32:09	305	-51
09/25/11	TRS102	MD8	ATL	35L	23:31:09	23:37:42	23:36:07	306	-95
09/26/11	SKW388L	CRJ	LAX	18L	01:36:15	01:37:00	01:37:44	307	44
09/29/11	COA1032	B73V	IAH	17R	11:58:01	12:03:00	12:03:41	308	41
09/29/11	AAL2385	MD8	IAH	18L	12:16:07	12:19:00	12:19:53	309	53
09/29/11	SKW5839	CRJ	IAH	17R	20:27:13	20:34:00	20:34:01	310	1
09/29/11	SKW2045	CRJ	IAH	35L	00:40:22	00:49:12	00:53:21	311	249
09/29/11	AWE273	B73S	IAH	35L	23:37:09	23:44:04	23:50:20	312	376
09/29/11	COA1183	B757	IAH	35L	00:37:27	00:41:06	00:43:29	313	143
09/29/11	SKW5846	CRJ	IAH	35L	00:40:08	00:43:00	00:48:49	314	349
09/29/11	SKW4455	CRJ	IAH	35L	00:23:17	00:29:00	00:28:40	315	-20
10/06/11	COA1502	B73V	IAH	17R	21:42:07	21:47:00	21:49:00	316	120
10/06/11	EGF2883	EMBJ	HOU	18L	23:05:23	23:09:00	23:11:51	317	171
10/07/11	ATN517	DC8S	IAH	18R	13:22:06	13:34:23	13:34:58	318	35
10/09/11	BTA4326	EMBJ	IAH	35L	16:36:57	16:40:00	16:41:10	319	70

Date (L)	Callsign	Type	Dest	Rwy	CFR done	Release	OFF	OTC?	OTC
10/09/11	AAL1591	MD8	IAH	35L	16:09:26	16:19:46	16:18:52	320	-54
10/09/11	AAL1897	MD8	IAH	36R	19:51:07	19:56:00	19:54:35	321	-85
10/10/11	COA1502	B73V	IAH	35L	21:35:38	21:36:00	21:39:45	322	225
10/10/11	EGF3254	EMBJ	HOU	36R	22:14:18	22:20:00	22:20:41	323	41
10/10/11	AAL2489	B757	LAX	36R	01:32:13	01:37:00	01:40:23	324	203
10/10/11	SKW388L	CRJ	LAX	36R	01:42:35	01:42:30	01:44:06	325	96
10/11/11	DAL2110	B757	ATL	17R	18:18:11	18:25:00	18:23:13	326	-107
10/12/11	AAL1001	MD8	IAH	35L	23:11:03	23:15:00	23:14:22	327	-38
10/17/11	BTA4326	EMBJ	IAH	17R	15:13:27	15:15:00	15:18:27	328	207
10/17/11	SKW5215	CRJ	IAH	17R	15:09:33	15:09:00	15:13:45	329	285
10/17/11	AAL1591	MD8	IAH	17R	15:20:43	15:25:00	15:25:02	330	2
10/17/11	COA1239	B73V	IAH	17R	15:35:49	15:39:00	15:40:53	331	113
10/18/11	EGF3254	EMBJ	HOU	36R	21:58:35	22:00:04	22:01:42	332	98
10/19/11	DAL1564	EA32	DTW	35L	22:28:33	22:34:10	22:36:14	333	124
10/23/11	AAL1591	MD8	IAH	17R	14:58:35	15:05:39	15:05:19	334	-20
10/23/11	AAL2222	MD8	ATL	35L	21:20:16	21:26:00	21:25:48	335	-12
10/25/11	COA1096	B738	IAH	17R	11:56:30	12:01:00	12:01:19	336	19
10/25/11	AAL2385	MD8	IAH	17R	12:10:49	12:20:46	12:19:03	337	-103
10/25/11	EGF3298	EMBJ	HOU	18L	12:45:07	12:53:53	12:53:08	338	-45
10/25/11	EGF3219	EMBJ	HOU	18L	14:16:14	14:22:00	14:21:51	339	-9
10/25/11	EGF3215	EMBJ	HOU	17R	15:15:15	15:17:00	15:18:19	340	79
10/27/11	EGF3219	EMBJ	HOU	36L	14:01:45	14:07:00	14:07:11	341	11
10/27/11	AAL1001	MD8	IAH	35L	23:07:25	23:10:15	23:11:48	342	93