Eighth USA/Europe Air Traffic Management Research and Development Seminar (ATM2009)

Linking Traffic Management to the Airport Surface

Departure Flow Management and Beyond

Nathan A. Doble, John Timmerman, Ted Carniol, and Mark Klopfenstein
Metron Aviation
Dulles, VA, USA

Midori Tanino and Ved Sud
Federal Aviation Administration
Washington, DC, USA

***Abstract*—Airport surface operations are largely managed tactically today, and there is little linkage between surface operations and traffic flow management (TFM) decision-making for other National Airspace System resources. The Next Generation Air Transportation System (NextGen) envisions airport operations that are more strategically planned, and which are better aligned with traffic management initiatives for terminal area and en route airspace. This paper describes the Departure Flow Management (DFM) capability, which translates TFM constraints to departure timing decisions and is an interim step in the evolution to NextGen. Results from DFM prototype field trials are presented. In addition, the Tower Flight Data Manager capability is introduced, which will further integrate TFM constraints with airport surface processes, including taxi planning and pre-pushback gate operations.**

Keywords-traffic flow management; departure; surface; airport

I. Introduction

In today's National Airspace System (NAS), imbalances between air traffic demands and resource constraints are addressed using traffic management initiatives (TMIs) that are implemented in a largely independent manner by traffic management specialists who have limited awareness of how their actions may affect traffic flows across or within another NAS resource. At lower volumes of traffic, this method can produce acceptable, though inefficient, NAS-wide traffic flow management (TFM) solutions. However, as traffic volumes grow and NAS resources operate closer to their maximum capacities, TFM problems can no longer be solved in isolation if a satisfactory system-wide outcome is to be achieved. TFM decisions must be integrated among the airport surface, terminal area, and en route airspace domains in order to extract maximum efficiency from the NAS.

As an example, consider today's tactical Approval Request (APREQ) process (also referred to as Call For Release), in which an Airport Traffic Control Tower (ATCT) is required to request via telephone a release (i.e., departure) time from an overlying Air Route Traffic Control Center (ARTCC) to ensure that the departure flight will fit into the overhead flow of traffic [1]. The allocation of APREQ slots is not coordinated with strategic TMIs, so the available APREQ release times may conflict with departure time windows assigned by Ground Delay Programs (GDPs) or Airspace Flow Programs, possibly resulting in additional airborne delay that could have been absorbed more efficiently pre-departure. In addition, the cumbersome, telephone-based APREQ procedure provides ATCT personnel with little insight into the constraints that the ARTCC is trying to satisfy, consequently making it difficult for the ATCT to conduct surface operations (such as departure queue management) in a way that most efficiently satisfies these constraints. Similarly, Flight Operations Center (FOC) personnel could more efficiently manage their operations (such as passenger loading and gate pushback) if they were provided information concerning APREQ delays in advance.

The Next Generation Air Transportation System (NextGen) envisions a distributed decision-making environment, in which TFM decisions are made locally with awareness of NAS-wide effects and NAS users play a greater role in the decision-making process [2]. NextGen also calls for modernized airport processes that are strategically planned and better aligned with terminal area and en route constraints in order to achieve gate-to-gate trajectory-based operations. As an interim step in the evolution to this NextGen vision, the Federal Aviation Administration (FAA) has developed and prototyped the Departure Flow Management (DFM) capability, which translates terminal area and en route TFM restrictions to takeoff timing constraints. This paper describes the DFM prototype system and presents results from recently completed DFM field trials. In addition, the Tower Flight Data Manager (TFDM) capability is introduced. TFDM will further link airport surface operations to TFM constraints by incorporating terminal area and en route weather and capacity information into ATCT and FOC decisions prior to departure, including taxi planning and pre-pushback gate operations.

II. Background

A. Current Practices

The pre-departure process for aircraft to become airborne into today's NAS can involve substantial coordination between many organizational elements of the Air Navigation Service Provider (ANSP). Typically, it includes multiple operational positions within the ATCT and Traffic Management Units (TMUs) at both the associated Terminal Radar Approach Control (TRACON) and the ARTCC serving the departure airport. The amount of coordination needed is typically related to not only the complexity and activity level of the departure airport, but also such factors as the number of other airports within the terminal area, whether the departures will be joining established overhead traffic flows, the presence of convective weather near the terminal area or the flight's route, and constraints in the aircraft's destination area. Coordination methods primarily rely on individual phone calls and direct conversations, use of blanket restrictions (such as a Miles-In Trail (MIT) or Minutes-In-Trail (MINIT) restriction for all flights crossing a particular departure fix), and manual recording of data. While some interactions also occur with the FOCs, in today's system flight-specific coordination with the FOC is for the most part relatively limited beyond the filing of the flight plan the aircraft intends to utilize and cancellation-related departure slot substitutions.

To help illustrate the operational functions within the ATCT that are involved in handling flights on the airport surface, Fig. 1 shows a representation of a typical high-activity ATCT and the sequence of events leading to the flight departing. ATCT functions may be combined or duplicated depending on airport activity and configuration, but for the purpose of this paper they are described discretely.

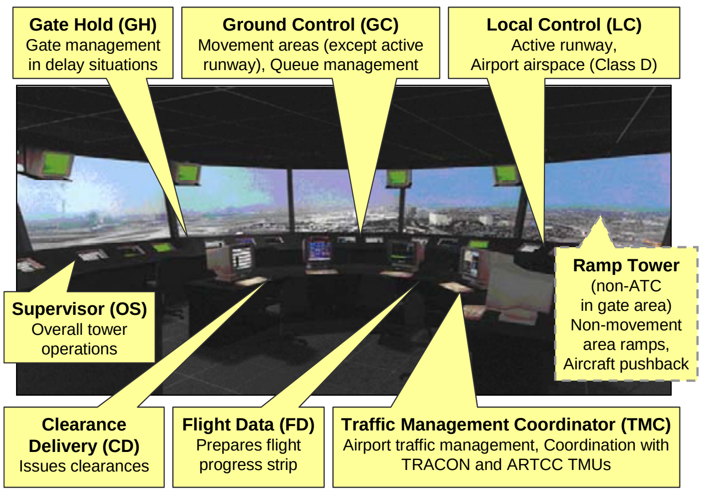

Figure 1. ATCT Positions and Functions: Coordination Among Multiple Positions is Required for Airport Surface Operations

The main event sequence for flights departing from such a high-density airport is as follows:

1. If weather or traffic demand constraints are anticipated to affect the flight, the Traffic Management Coordinator (TMC) coordinates with the TRACON and ARTCC TMU for changes to the aircraft's route for weather or departure fix demand balancing. The flight plan is revised accordingly
2. Flight Data (FD) posts the Flight Progress Strip associated with the flight in the appropriate strip bay.
3. Clearance Delivery (CD) prepares the Air Traffic Control (ATC) clearance by adding runway and departure route sensitive data to the flight plan in the Pre-Departure Clearance system and enables the ATC clearance transmission.
4. The flight obtains its clearance via data link, from a gate printer, or via voice communications with CD. If a GDP is in effect for its arrival airport, the flight also obtains the Expected Departure Clearance Time (EDCT) reflecting when it should become airborne.
5. If Gate Hold (GH) or departure metering procedures are in effect, the flight or ramp tower obtains anticipated pushback times and pushback approval from GH.
6. If necessary, when the aircraft is ready to taxi, the TMC coordinates through an APREQ process with TRACON and/or ARTCC TMUs for a departure release time that accounts for both overhead stream and departure fix constraints.
7. Ground Controller (GC) provides taxi instructions and sequences the aircraft into appropriate queues for departure runways and fixes.
8. Local Controller (LC) issues takeoff clearance consistent with EDCT and release times.

Frequently, to reduce coordination between the ATCT and TRACON TMU, departure release queuing will be accomplished through independent MIT or MINIT restrictions to the various ATCTs in the terminal area. Similarly, the ARTCC TMU may employ MIT restrictions with the TRACON in lieu of individual aircraft coordination. While the MIT restrictions do provide metering of traffic over departure fixes or into the overhead stream, they inherently result in both "bunching" and excessive gaps between aircraft. This has the effects of increasing controller workload associated with sequencing and lessening throughput.

B. *Relevant Research*

Much research has been conducted to assist and automate the pre-departure process for an aircraft to become airborne.

The Departure Spacing Program (DSP) is a prototype tool intended to improve the efficiency of departure traffic scheduling and coordination. DSP evaluates the schedules and routes of flights from participating airports, calculates departure fix demand/loading, and assigns departure time windows based on projected fix crossing times. DSP automates inter-facility coordination of schedules and clearances. DSP was first prototyped in the Los Angeles basin from 1990 to 1994. Prototype development was re-initiated in the New York metropolitan area in 1998. The initial focus was on automating routine coordination communications between the major ATC facilities. This feature has been used regularly since April 2000 at the New York ARTCC, New York TRACON, and seven ATCTs. Prior to DSP, ATCTs had to provide their proposed flights to the New York ARTCC Departure Complex (the Departure Pit) and their departure line-up to the TRACON via telephone calls. With the implementation of DSP, clearance delivery and airport departure lineup monitoring has been automated to a large extent. Consequently, much of the coordination and communications bottleneck at the Departure Pit has been eliminated.

NASA Ames Research Center, in cooperation with the FAA, has studied automation for aiding surface traffic management. The Surface Management System (SMS) is a decision support tool that (1) provides information and advisories to help traffic managers, controllers, and air carriers collaboratively manage the movements of aircraft on the surface of busy airports, thereby improving capacity, efficiency, and flexibility; and (2) increases shared situational awareness of airport surface operations between the ATCT, the ramp tower, air carriers, and various airport authorities and other ATC facilities [3].

Currently, the FAA is developing a suite of capabilities to improve departure congestion management. One component of this is TFM Surface Data Integration (TSDI), which processes airport data from various automation and surveillance systems (e.g., Airport Surface Detection Equipment, the Electronic Flight Strip Transfer System, Automatic Dependent Surveillance-Broadcast, and airline-provided event data) to produce information on actual surface events, predicted surface events, and surface metrics. This standardized information is intended for integration into TFM decision support tools.

For airports within Europe, Eurocontrol has embarked on similar efforts to integrate TFM with airport operations and to improve collaborative decision making involving those operations [4]. The Airport CDM program focuses on all airport stakeholders having a common understanding of the airport situation and improved decision-making [5]. Those capabilities have matured through field trials and interfaces with the Eurocontrol Central Flow Management.

III. Departure Flow Management

Departure Flow Management (DFM) is a capability seeking to increase departure flow efficiency by automating the coordination of departures from multiple airports over shared and congested NAS resources via improved decision support capabilities and web-based, electronic communications [6]. Traffic managers in the ARTCC monitor departure and en route demand, initiate DFM departure procedures, and monitor the traffic flow. DFM allocates departure times to the affected airports, and traffic managers at the airports assign these times to the departures at their facilities. Compared to the current APREQ process, the automated calculation, communication, and assignment of departure times reduce workload and increase departure flow efficiency. The DFM concept builds upon previous NASA research into automation of the APREQ process [7].

A. Motivation

DFM addresses a number of limitations and inefficiencies in the current APREQ process. Because APREQ requests are handled via telephone, the APREQ process must be performed serially (with the exception of handling multiple requests from a single ATCT in a single phone call). Observations at the Cleveland ARTCC (ZOB) showed that this process requires an average of 41 seconds from the time the ATCT first calls a TMC to the time the TMC ends the phone call. Table I shows the mean APREQ processing times observed at ZOB during the week of August 27, 2007. The APREQ process is separated into two components: ATCT Wait Time (the difference between the time the ATCT placed the call and the time the TMC answered the call) and Call Duration (the difference between the time the TMC answered the call and the time the call was ended). Results are shown for the Cleveland (CLE), Detroit (DTW), and Pittsburgh (PIT) airports, as well as averages across all airports calling ZOB.

TABLE I. OBSERVED MEAN APREQ PROCESSING TIMES AT ZOB USING TELEPHONE COORDINATION

APREQ Component (sec)	Departure Airport			
	CLE	DTW	PIT	All ZOB
ATCT Wait Time	11.6	12.3	14.3	13.8
Call Duration	28.2	30.0	29.7	27.3
Total Time	39.8	42.3	44.0	41.1

During exceptionally busy periods, it is not unusual for an ATCT to hang up before the TMC has a chance to answer the telephone. If the time required to perform the APREQ process were reduced, this would allow both ARTCC and ATCT personnel to focus on other important tasks.

In addition, the current APREQ process does not provide ATCTs with any visibility into the traffic flow constraints that the TMC is trying to satisfy. The likely magnitude of departure delays can only be estimated through prior experience, and no information is provided to ATCTs concerning the saturation of the overhead flow. Field observations have shown that this leads some ATCTs to initiate APREQ calls at exceptionally long lead times—over 20 minutes prior to the desired departure time—in order to reserve a departure slot and avoid large delays. Fig. 2 shows the distribution of lead times observed at the Los Angeles ARTCC (ZLA) during the week of January 28, 2008.

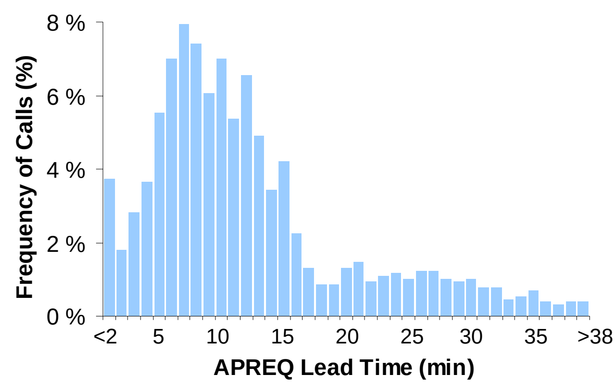

Figure 2. Distribution of Observed APREQ Lead Times at ZLA, Showing Prevalence of Long Lead Times (> 20 minutes)

At such long lead times, there is a high probability that the release time could become unachievable due to issues such as aircraft maintenance, passenger boarding delays, or taxiway congestion. This causes a higher incidence of release time non-compliance (i.e., not departing within a specified tolerance of the assigned release time) and release time revisions than necessary, which increases workload and may result in unused overhead flow capacity.

Finally, the manual APREQ process does not allow for efficient recording of data for use in calculating performance metrics, such as departure time compliance, the frequency of departure time revisions, and the magnitude and equity of departure delays. If this information were available, it could be used to compare APREQ performance across airports and airlines in order to quickly identify problem areas and further improve the efficiency of the NAS.

B. *Interfaces and System Architecture*

The DFM prototype has two interfaces: one designed for ARTCC TMC use and one designed for ATCT use. The DFM ARTCC interface shows multiple traffic flow timelines (Fig. 3). These timelines show aircraft that will need release times and aircraft with requested or assigned release times. The timelines are color-coded to indicate when a flow restriction is in place and which times are available for crossing the restricted NAS resource. The DFM ATCT interface shows similar information (Fig. 4). However, the ATCT interface is tailored to show only the particular airport's departures. Also, the ATCT timeline shows available/unavailable departure times rather than resource crossing times.

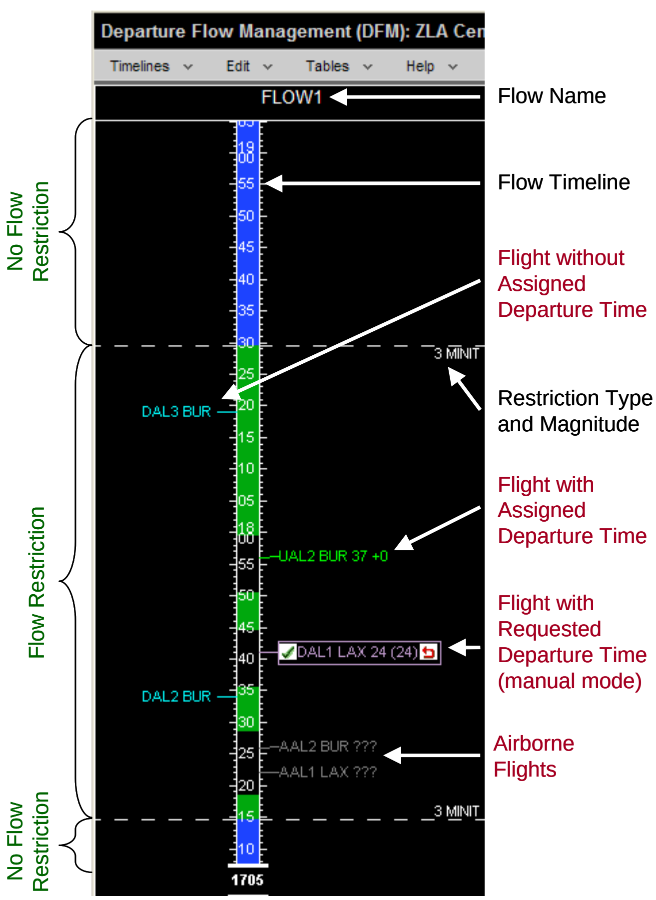

Figure 3. Single Flow Timeline on Prototype DFM ARTCC Interface

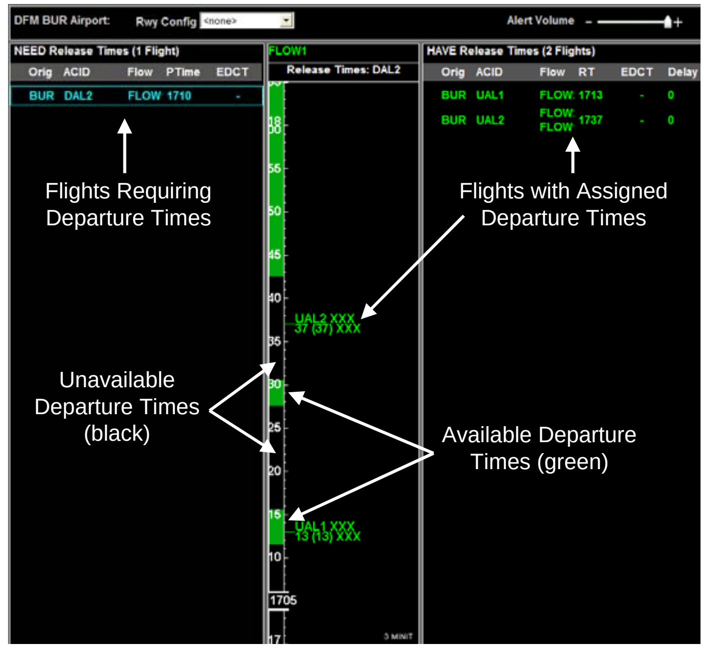

Figure 4. Prototype DFM ATCT Interface

In the development of the DFM user interface, several ideas were leveraged from NASA's Center-TRACON Automation System research. In particular, the timeline-based display format was modeled after the Traffic Management Advisor interface [8].

To begin using DFM, TMCs at the ARTCC first configure the flows and the restrictions for each flow. Multiple flows can be defined. Within each flow, multiple MIT or MINIT restrictions can be scheduled (e.g., 5 MIT from 1200Z to 1400Z, then 10 MIT from 1500Z to 1600Z), and the restrictions can be filtered to only include particular departure airports.

To request a DFM departure time, ATCT personnel drag-and-drop flights onto their timeline to indicate the desired departure time. DFM automatically places the flight at the earliest available release time (at or after the requested time) that satisfies all of the restrictions with which the flight must comply. Two approval modes may be used—manual approval or automatic approval—as configured via the ARTCC interface. Using manual approval, the DFM-calculated earliest available time is shown on the ARTCC timeline along with the requested time. The TMC then approves the request via a mouse click or drags-and-drops the flight to a time of their choosing. Using automatic approval, the DFM-calculated time is automatically approved and assigned without TMC intervention. For situations in which an aircraft is ready to depart earlier or later than anticipated, DFM allows ATCT personnel to quickly identify any available alternative departure times without calling the ARTCC.

The DFM architecture leverages existing FAA capabilities and can be easily deployed across multiple FAA facilities. The process for defining traffic flows uses the existing Flow Evaluation Area functionality within the Traffic Flow Management System (TFMS), and the algorithms for calculating available departure times also use TFMS trajectory prediction logic.

The ARTCC and ATCT DFM interfaces are displayed as thin-client internet web pages, supported by centrally-located servers. The web pages use Asynchronous Java and XML (AJAX) technology, along with Dynamic Hypertext Markup Language, Cascading Style Sheets, and Java Servlets, to provide a rich user experience despite the interface being rendered on a web browser. This architecture requires minimal infrastructure to implement DFM at ATCTs and ARTCCs, allows users the freedom to create cross-ARTCC restrictions, and supports a highly scalable and easily maintainable system for the future.

The DFM architecture was influenced by previous NASA research that showed the feasibility of a web-based architecture for departure management systems [9].

C. *Field Trial Overview*

Two DFM field trials have been conducted to date, at ZOB and ZLA. The ZOB field trial was conducted during August-October 2007; participants included ZOB TMCs and ATCT personnel at the CLE, DTW, and PIT airports. The ZLA field trial was conducted during January-March 2008; participants included ZLA TMCs and ATCT personnel at the Burbank (BUR), Las Vegas (LAS), Los Angeles (LAX), Ontario (ONT), and San Diego (SAN) airports. Each field trial consisted of three phases, each lasting approximately one week.

ZOB and ZLA were chosen as field trial sites because they illustrate different applications for DFM. At ZOB, APREQ procedures are used daily for departures from ZOB airports (such as CLE, DTW, and PIT) to satisfy MIT restrictions for congested overhead traffic flows between the Chicago and New York metropolitan areas. At ZLA, APREQ procedures are used at ZLA to schedule arrivals to airports such as LAS and Phoenix. In addition, independent MIT restrictions (e.g., 10 MIT for LAX departures, 15 MIT for BUR departures, etc.) are applied to flights from Los Angeles basin airports to control volume in congested departure sectors.

1) *Phase 1: Baseline Data Collection*

Because APREQ usage varies from ARTCC to ARTCC, the purpose of Phase 1 was to gather quantitative and qualitative data to characterize the current APREQ operations at each facility. Researchers noted the flows and times for which MIT restrictions were used. For all flights subject to APREQ, call durations and assigned delays were recorded. These data were then used to select the flows and time periods for the Phase 2 and Phase 3 testing, as well as to identify any software changes that were needed prior to starting the subsequent phases.

2) *Phase 2: Shadow Testing*

The purpose of this phase was to mimic current APREQ operations using the DFM prototype, in order to validate the prototype software and qualitatively assess the applicability of the DFM operational concept to each facility. In this phase, researchers used DFM to request and assign the same departure times as the ARTCC and ATCT personnel, but the actual APREQ process was still performed via telephone. This phase allowed the DFM test team to verify the stability and accuracy of the DFM algorithms, the reliability of the software, and the ability to transfer data between the ARTCCs, ATCTs, and the DFM data server at the FAA Air Traffic Control System Command Center.

3) *Phase 3: Operational Testing*

The purpose of this phase was to use DFM in an operational setting for proof-of-concept testing. For selected flows and airports, DFM prototype interfaces (instead of telephones) were used by ARTCC and ATCT personnel to request and assign departure times. Although researchers were present to assist when necessary, this phase allowed the DFM functionality and interface to be tested in near-operational conditions by the users for which the system was designed, thus validating the DFM communication concept and testing the trajectory modeling, departure slot identification, and release time calculation algorithms. In addition, qualitative and quantitative user feedback provided insight into the usability of the DFM interface and desirability of the DFM capabilities.

D. *Field Trial Results*

Here, results are presented from the initial ZOB and ZLA field trials. The results include APREQ processing time, lead time, departure compliance, and sector loading data, as well as the responses to questionnaires given to DFM users.

1) *APREQ Processing Times*

Prior to the field trials, it was hypothesized that using DFM would reduce the time required to request and approve departure release times. Fig. 5 shows mean APREQ processing times during the ZOB field trial. Across all airports, DFM usage reduced average APREQ processing times by 24% (31.1 sec in Phase 3 vs. 41.1 sec in Phase 1). The ZOB Phase 3 data primarily includes releases using Manual mode; in Automatic mode, the total processing time was only a few seconds. Total sample sizes were 1562 calls in Phase 1 and 57 calls in Phase 3. Similar results were seen for the ZLA field trial.

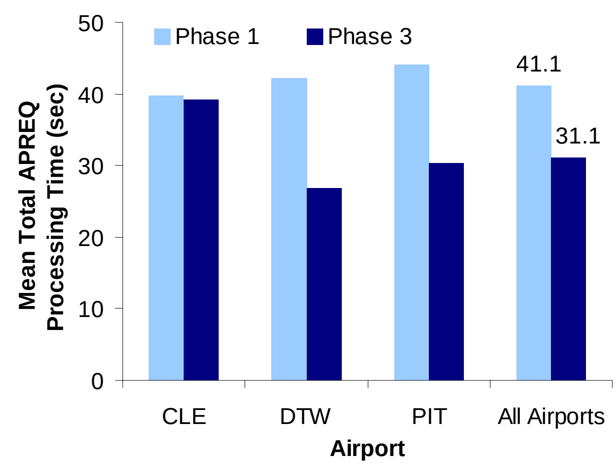

Figure 5. ZOB Mean Total APREQ Processing Times, Showing Overall Decrease When DFM is Used

2) *APREQ Lead Times*

Prior to the field trials, it was hypothesized that using DFM may change the distribution of APREQ lead times (i.e., the difference between the ATCT-initiated APREQ request and the desired departure time), as DFM would provide ATCTs with better situational awareness of departure constraints. In particular, it was hoped that DFM usage would reduce the frequency of exceptionally long lead times (e.g., those greater than 20 minutes). Departure releases assigned with these long lead times often require subsequent revisions (and, therefore, additional telephone calls) when the desired departure times change due to passenger and luggage loading, catering, crew, or maintenance delays. It was hypothesized that DFM would show ATCTs that—in many situations—sufficient departure slots are available at shorter lead times. Fig. 6 shows mean APREQ lead times for the five airports included in the ZLA field trial.

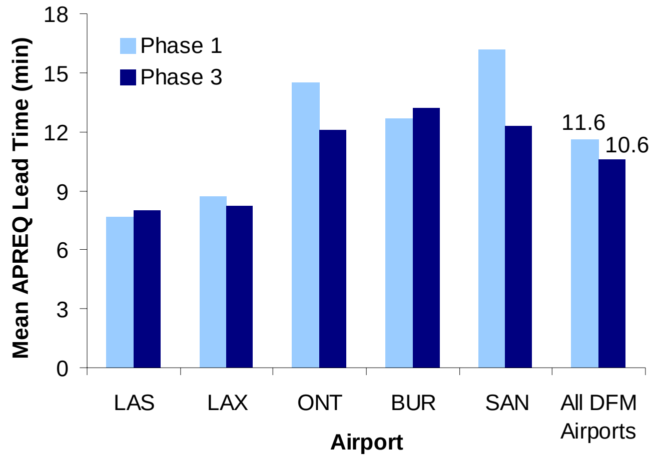

Figure 6. ZLA Mean APREQ Lead Times, Showing Overall Decrease When DFM is Used

Overall, lead times were reduced from Phase 1 to Phase 3 by an average of one minute (11.6 min to 10.6 min). This difference was significant ($t(1431) = 2.82$, $p < 0.05$). At SAN, which had the largest mean lead time in Phase 1, DFM usage reduced the average lead time by 3.6 minutes (16.3 min to 12.7 min). This difference was also significant ($t(297) = 3.47$, $p < 0.05$). Results for the other individual airports were not significant at the 0.05 level.

3) *Departure Time Compliance*

Prior to the field trials, it was hypothesized that DFM usage would improve compliance with departure release times because ATCTs would have greater awareness of the consequences of non-compliance and greater control over release time selection. ZLA uses a -2/+1 minute compliance window around the assigned release time. Fig. 7 shows the compliance rates for the five airports included in the ZLA field trial.

As predicted, compliance improved or remained constant for all airports. Not surprisingly, the airport with the largest lead time reduction (SAN) also saw the largest compliance increase when using DFM (from 62% in Phase 1 to 77% in Phase 3).

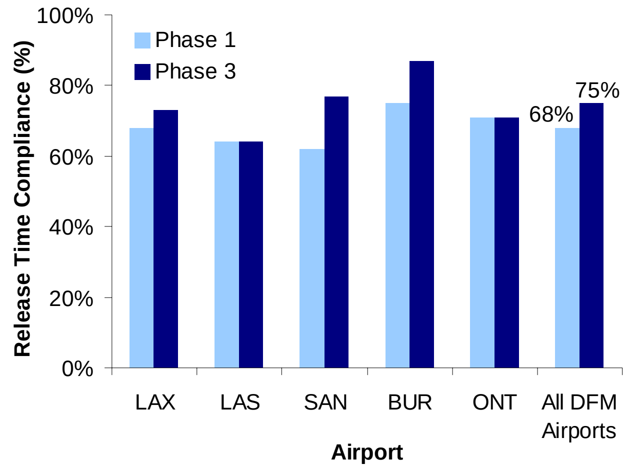

Figure 7. ZLA Departure Release Time Compliance, Showing Overall Increase When DFM is Used

4) *Sector Loading*

At ZLA, independent MIT restrictions are typically placed on departures from Los Angeles area airports that depart via the GMN navigational aid, located in ZLA Sector 27. Because the departure times are not coordinated among airports, this can result in insufficient or excessive gaps between departures. During Phase 3 of the ZLA field trial, DFM was used to coordinate departures on the GMN flow. During the field trial, the ZLA Area Supervisor responsible for Sector 27 indicated that they were able to operate this sector at a higher traffic level than normal due to the smoother flow provided by DFM. A subsequent analysis of Sector 27 traffic loads confirmed this observation. Fig. 8 shows the maximum number of flights in this sector during 15-minute time bins (a common metric used by ATC personnel to measure demand) on three days when DFM was used to control the GMN flow. For comparison, the same time periods from the previous week (during the Phase 2 observations) are also shown.

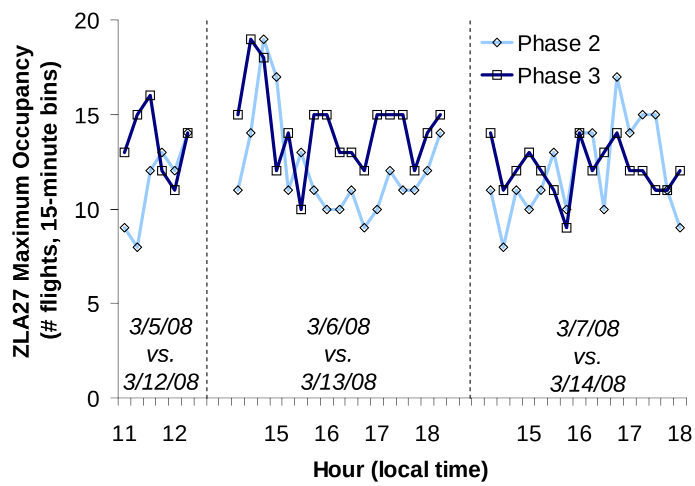

Figure 8. ZLA Sector 27 Maximum Instantaneous Sector Occupancy, Showing Overall Increase When DFM is Used

Overall, sector loading increased by an average of 10% (12.0 to 13.2 flights) when DFM was used. Although flights not controlled by DFM also transited the sector, this result shows that a coordinated departure flow has the potential to increase sector capacities.

5) User Feedback

DFM users were asked to complete questionnaires after Phase 3 of the ZOB and ZLA field trials. The questionnaires contained four statements to be rated on a Likert scale, as well as free-response questions. The Likert scale responses were generally positive, and are shown in Table II. For nearly all of these statements, ZLA responses were more favorable than ZOB responses. This is likely partially due to improvements to the prototype interface made after the ZOB field trial. In addition, the ZLA field trial made larger use of DFM's Automatic mode, which, compared to DFM's Manual mode or telephone requests, gives ATCT users the most control over the APREQ process and the most streamlined procedure.

TABLE II. DFM FIELD TRIAL QUESTIONNAIRE RESPONSES

Statement	Mean Response *1 = strongly disagree, 7 = strongly agree*			
	ZOB ARTCC *(n=5)*	**ZOB ATCTs** *(n=1)*	**ZLA ARTCC** *(n=8)*	**ZLA ATCTs** *(n=10)*
DFM is useful.	4.2	5.0	5.8	6.5
DFM is easy to use.	4.6	6.0	5.1	6.6
DFM creates more time for me to manage other issues and/or procedures within the TMU/Tower.	4.2	4.0	4.3	6.1
DFM provides access to the information that I need to manage the APREQ process.	4.4	3.0	4.3	6.2

Answers to the free-response questions were also generally positive. Most negative responses regarded minor interface details such as font sizes, and they often included an acknowledgment that their confidence in DFM operations would likely improve as the prototype evolved and they gained more experience with the system.

Feedback from ARTCC users included:

- *"DFM should reduce the 'unnecessary' and allow us to concentrate on the important."*
- *"With DFM, we can see what's happening and still be on the phone doing other things."*

Feedback from ATCT users included:

- *"DFM is extremely progressive and something that we really need. It is easy to be trained on and it is intuitive."*
- *"Situational awareness and flexibility and planning [are] vastly improved. The fact that we're able to see what is available and what is not instead of the [ARTCC] TMU being the only ones who really know what's going on was something I'm very pleased with."*

In addition, the LAX ATCT Supervisory TMC reported:

- *"After the [ZLA] field trial, DFM was rated for functionality, usefulness and effectiveness. No one gave it a rating less than 80-100% positive in any area. Unheard of for a first field system trial."*

E. Next Steps

Based on the success of the DFM field trials, the FAA is planning a more extensive field evaluation in 2009 that will involve three ARTCCs and several of their major underlying ATCTs. The DFM capabilities will then be incorporated into the Departure Information Services (DIS) system, which is currently under development. The DIS system will provide functionality to assist rerouting, as well as flow management and monitoring capabilities that will allow both the ATCT facilities and the ARTCC TMU to track controlled departure time compliance and the state of the overhead flow over time. The DIS concept will provide flexible and responsive tools and procedures to account for uncertainty on the surface and in the en route airspace. Concept exploration is also underway to extend this concept to a multiple ARTCC capability, and to provide DIS-generated information to airlines.

IV. EVOLUTION TO NEXTGEN

As currently envisioned, in the NextGen environment there will be a reapportionment of roles among the ANSP, FOC, and aircraft. Among the identified responsibility changes between ANSP and FOC that directly relate to airport surface terminal operations is: "As operators plan flights, they share information with the ANSP about the planned trajectory of the aircraft….As more information becomes available about the conditions affecting a flight, operators are automatically informed and in turn, make adjustments to provide 'best–known' information updating their flight plans." [2] Similarly, there are also airport surface responsibility changes on the horizon between ANSP and aircraft: "Trajectory-based procedures may be used on the airport surface at high-density airports to expedite traffic and schedule active runway crossings. Equipped aircraft may perform delegated separation procedures, especially in low-visibility conditions." [2]

A. Tower Flight Data Manager

Achieving the NextGen vision for airport surface operations is dependent on many new capabilities and enhancements that are needed to support the responsibility shifts and to achieve NextGen goals for greater capacity, efficiency, and safety, as well as reductions in environmental impacts. One capability which will help achieve the NextGen goals is TFDM. TFDM is envisioned to consist of an integrated suite of tools that will be used to electronically manage flight data and coordinate surface operations in the ATCT. TFDM will go beyond the capabilities of DFM and further link TFM constraints to airport surface planning through such features as improved pre-departure situational awareness, transfer of departure queue management from the taxiway environment to the gate and ramp areas, improved departure sequencing, taxi conformance monitoring, departure runway assignment, airport performance analysis, and conflict-free taxi planning.

Many of the TFDM capabilities will be supported by the Arrival/Departure Management Tool (A/DMT). A/DMT is a set of user support tools within TFDM that will develop and manage an integrated plan for arrival and departure operations at the airport, based on 4-D trajectory assignments. A/DMT seeks to reduce engine emissions on the airport surface, to permit more efficient use of gates and holding areas, and to enhance the safety of surface operations. The transition from manual flight strip processes within the ATCT to electronic flight data through TFDM enables the practical application of many of these capabilities.

TFDM research is proceeding through the collaborative efforts of government, industry, and academia. The FAA is providing overall direction and funding, and MIT Lincoln Laboratory is managing the specific research and prototype development efforts, including A/DMT. Prototype development and evaluation is planned through a segmented approach, spanning the 2010-2017 timeframe.

B. Departure Scenario in TFDM Environment

The following short scenario of a typical high-density airport flight departure on a day with convective weather along the aircraft's intended trajectory reflects the airport surface environment following deployment of TFDM capabilities:

The scenario starts with the FOC filing a flight plan well before departure. The flight plan contains not only the flight's intended trajectory, but also rank-ordered alternatives with the effective time horizon for each. TFMS analyzes the trajectory alternatives and selects the most appropriate for anticipated system demand and weather constraints. The FOC is provided information on the selected trajectory and expected departure time. The FOC adjusts gate planning, aircraft fueling and servicing, and passenger boarding accordingly. Traffic management personnel in the ATCT, TRACON, and ARTCC are presented timelines of departure slots and aircraft expecting to depart. The departure slots are reflective of constraints associated with destination airport, overhead stream, departure fix, and airport surface. A departure slot is selected and TFDM calculates the time that the aircraft needs to push back from the gate; this information is provided to the FOC/ramp tower. The FOC/ramp tower adjusts aircraft servicing and passenger boarding; the aircraft pushes back by the specified time. Meanwhile, within the ATCT, the CD controller is formulating the aircraft's ATC clearance and enabling it for pre-departure data link receipt by the aircraft when ready. A few minutes before pushback, the aircraft obtains its clearance. The aircraft pushes back at the designated time and contacts GC for taxi clearance. Since the departure queue management is now moved back from the taxiways and departure runway vicinity to the gate area, the aircraft makes an uninterrupted, continuously moving taxi to the end of the departure runway. While taxiing, the aircraft's progress is monitored for conformance with its issued taxi route and with its progress along the route towards meeting the planned departure time; alerts are generated as needed for deviations in both route and progress. At the planned release time, LC clears the aircraft for takeoff. The aircraft departs and melds into the trajectories of aircraft over the departure fix and overhead stream without significant airborne changes to its trajectory.

C. Near-Term Research Activities

In the near term, TFDM development activities will focus on leveraging and integrating existing research products and concepts. The functionality within DFM will be used as the means to communicate TFM restrictions to TFDM. Other existing research planned for incorporation into TFDM includes the Route Availability Planning Tool (RAPT) and System Enhancements for Versatile Electronic Negotiation (SEVEN).

RAPT is an automated decision support tool intended to help air traffic controllers and airline dispatchers determine which departure routes will be affected by operationally significant convective weather up to 90 minutes into the future (a 30 minute planning window plus 60 minutes flight time). RAPT assigns a departure route status—green for clear, dark green for low impact, yellow for caution, and red for blocked—to future departures by combining precipitation and echo tops forecasts with a model for departure operations [10]. Within TFDM, RAPT functionality will be leveraged to add weather constraints to the DFM departure time availability algorithms.

SEVEN is a concept for managing en route congestion that allows NAS customers to submit prioritized lists of alternative routing options for flights. SEVEN provides traffic managers with a tool that algorithmically takes customer preferences into consideration as it assigns reroutes and delays to flights subject to traffic flow constraints. One of the most significant benefits is the ability to recapture system capacity that is currently lost when severe weather (or other capacity limiting factors) does not materialize as predicted [11]. Within TFDM, SEVEN functionality will be leveraged to provide a source of departure route alternatives, which will ensure that departures arrive at the runway threshold with a feasible departure route in cases when their highest-priority route is unavailable due to TFM or weather constraints.

These capabilities will be integrated into TFDM using an iterative concept engineering process including scenario and use case development, storyboard walkthroughs with subject matter experts, fast-time simulation, human-in-the-loop simulation with laboratory prototypes, shadow mode field testing, and operational field evaluations.

V. Conclusions

In conclusion, DFM is an important interim step toward realizing the NextGen vision for modernized airport surface processes and gate-to-gate trajectory-based operations. Through field trials, the DFM prototype system has already shown the potential for efficiency benefits and improved ATCT situational awareness of the impact of TFM constraints on departure decision-making. Going forward, TFDM will leverage the capabilities developed for DFM to further link TFM constraints to the airport surface domain for improved taxi planning and pre-pushback decision-making.

Acknowledgments

The authors would like to thank the Traffic Management Unit personnel at ZLA and ZOB, as well as the controllers and managers at the BUR, CLE, DTW, LAS, LAX, ONT, PIT, and

SAN airports for their participation in the DFM field trials. The authors would also like to thank MIT Lincoln Laboratory for its collaboration on the TFDM concept.

REFERENCES

[1] P. Kopardekar, S. Green, T. Roherty, and J. Aston, "Miles-in-trail operations: a perspective," AIAA 3rd Aviation, Technology, Integration, and Operations Forum, Denver, CO, 2003 (AIAA 2003-6700).

[2] Joint Planning and Development Office, "Concept of operations for the next generation air transportation system, version 2.0," Washington, DC, 2004. http://www.jpdo.gov/library/NextGen_v2.0.pdf

[3] S. Atkins et al., "Surface management system field trial results," AIAA 4th Aviation Technology, Integration, and Operations Forum, Chicago, IL, 2004 (AIAA 2004-6241).

[4] D. Böhme, "Tactical departure management with the Eurocontrol / DLR DMAN," 6th USA/Europe Air Traffic Management Research and Development Seminar, Baltimore, MD, 2005.

[5] Eurocontrol, "Airport CDM operational concept document – Version 3.0," Brussels, Belgium, 2006. http://www.euro-cdm.org/library/cdm_ocd.pdf

[6] A. Spencer et al., "Tactical airport departure flow management," 14th International Symposium on Aviation Psychology, Dayton, OH, 2007.

[7] P. Kopardekar et al., "Making internal departure release operations more efficient," AIAA 4th Aviation Technology, Integration, and Operations Forum, Chicago, IL, 2004 (AIAA 2004-6346).

[8] H.N. Swenson et al., "Design and operational evaluation of the traffic management advisor at the Fort Worth air route traffic control center," 1st USA/Europe Air Traffic Management Research and Development Seminar, Saclay, France, 1997.

[9] P. Kopardekar, S.M. Green, and P. Thompson, "Improving efficiency of departure release communications for en route overhead traffic flow management," 23rd Digital Avionics Systems Conference, Salt Lake City, UT, 2004.

[10] R. DeLaura and S. Allen, "Route selection decision support in convective weather: a case study of the effects of weather and operational assumptions on departure throughput," 5th USA/Europe Air Traffic Management Research and Development Seminar, Budapest, Hungary, 2003.

[11] M. Klopfenstein et al., "Congestion management via interactive dynammic flight lists and customer submitted multiple routing options," AIAA 5th Aviation Technology, Integration, and Operations Conference, Arlington, VA, 2005 (AIAA 2005-7436).

AUTHOR BIOGRAPHIES

Nathan A. Doble earned B.S and M.S. degrees in aeronautics and astronautics from the Massachusetts Institute of Technology, Cambridge, MA, USA, in 2001 and 2003, respectively.

He is currently a Senior Analyst with Metron Aviation, in Dulles, VA. Previously, he worked at The Titan Corporation, supporting Distributed Air/Ground Traffic Management research at the NASA Langley Research Center. He has also held internships at the MITRE Center for Advanced Aviation System Development, Seagull Technology, and the Honeywell Technology Center. His research interests have included traffic flow management, airborne capabilities for trajectory management, and air traffic control human factors.

Mr. Doble is a senior member of AIAA and serves on the AIAA Air Transportation Systems Technical Committee. He is also an instrument-rated private pilot.

John Timmerman attended the Florida Institute of Technology, Melbourne, FL, USA, majoring in aerospace engineering and computer science.

He joined Metron Aviation, in Dulles, VA, in 2008 as a Program Manager. Prior to this, he had a 37-year career with the Federal Aviation Administration, where he served in various managerial roles on the High Altitude Redesign, Unmanned Aircraft Systems, Contract Tower, Voice Switching and Control System, National Flight Data Center, Pre-Departure Clearance, and Automated Flight Service Station programs.

Mr. Timmerman is also a commercial pilot and flight instructor with single- and multi-engine airplane, instrument, and glider ratings.

Ted Carniol earned a B.A. degree in the integrated science program from Northwestern University, Evanston, IL, USA, in 1984, and a M.S. degree in mathematics from George Mason University, Fairfax, VA, USA, in 1989.

He joined Metron Aviation, in Dulles, VA, in 2001, and is currently responsible for corporate-wide business development as well as project-level management and technical lead activities for surface related technologies. Prior to this, he worked at Metron, Inc., where he designed, developed, and implemented mathematical models for the US government, covering such topics as cost-benefit analysis, mission planning, training and readiness measurement, asymmetric warfare, and exercise planning and reconstruction.

Mark Klopfenstein earned B.S. and M.S. degrees in aerospace engineering from the University of Virginia, Charlottesville, VA, USA in 1988.

He is currently the Director of Research & Analysis at Metron Aviation, in Dulles, VA. He has over 20 years experience conducting and overseeing concept engineering, advanced aviation research, airspace design and optimization, TFM operational analysis, environmental analysis, and investment analysis for a variety of customers including the FAA, NASA, and military clients. His primary focus is on TFM research and concept engineering in support of the FAA's Collaborative Decision Making initiative and other contracts in the aviation field.

Mr. Klopfenstein is a senior member of AIAA and a member of ATCA.

Midori Tanino earned a B.S. degree in computer science and a M.S. degree in electrical engineering from the University of Maryland, College Park, MD, USA.

She is currently the Manager of NextGen TFM Engineering for the FAA's Systems Operations Programs. She has been involved in the development of several Traffic Flow Management automation capabilities for the FAA. Her most notable accomplishments are the development and national deployment of the Ground Delay Program and Route Management capabilities.

Ved Sud earned a B. Tech. degree in electrical engineering from the Indian Institute of Technology, New Delhi, India, and a M.S. degree in computer science from the State University of New York, Stony Brook, NY, USA.

He is currently the FAA Lead Systems Engineer for Safety Management of all Traffic Flow Management Programs. He joined the FAA in 2002, working on research and project management of the FAA's Collaborative Decision Making program. From 2004 to 2008, he provided leadership on TFM research and strategic planning for TFM programs as the manager for Concept Engineering. In fall 2005, he initiated the FAA's Departure Flow Management research program. He retired from the MITRE Corporation, Center for Advanced Aviation System Development in 2002 after working there for 19 years on several FAA and international ATM projects.