



BASE YEAR FINAL PRESENTATION NASA CTD-SUBTOPIC 1 NRA: METHODS OF INCREASING TERMINAL AIRSPACE FLEXIBILITY AND CONTROL AUTHORITY

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EXECUTIVE SUMMARY

- ▶ Solicitation objective was to develop concepts and algorithms for making tactical adjustments (e.g., path stretch, speed adjustments) to strategically-planned arrival and departure trajectories
- ▶ During the course of the project, the objective changed to developing a “What-if” Analysis capability for Departure Metering Programs (DMP) in support of ATD-2
- ▶ A fast-time simulation-based What-if Analysis capability was developed and tested against three DMP use cases
 - ▶ Preliminary findings show that the DMP What-if Analysis capability can help the Departure Reservoir Coordinator (DRC) select values for key parameters, i.e.,
 - ▶ DMP Start and End Time
 - ▶ Target Departure Queue Length (TDQL)
 - ▶ Unscheduled Demand Buffer (UDB)

PRESENTATION OUTLINE

- ▶ Solicitation Objective
- ▶ Evolution of Project Objectives
- ▶ New Problem Focus—What-if Analysis
- ▶ What-if Analysis Simulation Platform
- ▶ What-if Analysis Use-Cases
- ▶ What-if Analysis Evaluation Results
- ▶ Conclusions and Discussion

PRESENTATION OUTLINE

- ▶ Solicitation Objective
 - ▶ Overview
 - ▶ Literature Review
 - ▶ Real-world Problem Selection
- ▶ Evolution of Project Objectives
- ▶ New Problem Definition—What-if Analysis
- ▶ What-if Analysis Simulation Platform
- ▶ What-if Analysis Evaluations
- ▶ Conclusions and Discussion

SOLICITATION OBJECTIVE

➤ Objectives

- Develop concepts and algorithms for making tactical adjustments to strategically-planned arrival and departure trajectories
- Path modifications such as path-stretches, and/or
- Temporal trajectory modifications such as speed adjustments
- Perform human-factors analysis of the developed concept

➤ Scope

- Select a set of three real-world problems for study
- Focus on terminal airspace arrival-departure interactions
- Emphasis on New York TRACON interaction-cases

➤ Completed Tasks & Deliverables

- Literature Review Report documenting relevant previous studies
- Real-world Problem Report and Briefing documenting 5 real-world problems of shared resources between arrivals and departures

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- ▶ What-if Analysis Evaluations
- ▶ Conclusions and Discussion

EVOLUTION OF PROJECT OBJECTIVES

- ▶ Desire to align project more closely with ATD-2 objectives
 - ▶ Focus on departure management
 - ▶ ATD-2 sites unknown, shift focus to DFW as surrogate

- ▶ Series of interviews with Greg Juro/D10 TRACON
 - ▶ Identify DFW arrival/departure/surface interactions that complicate scheduling of departures

- ▶ DFW not a good candidate for developing tactical departure traffic management tools
 - ▶ Not many arrival-departure interaction problems
 - ▶ Significant airspace available for last minute trajectory adjustments
 - ▶ Numerous strategic departure problems (e.g., meeting and resolving multiple MITs on single aircraft, scheduling takeoffs to meet MITs, etc.), but not many tactical control problems

DEVELOP SURFACE-TERMINAL WHAT-IF ANALYSIS CAPABILITY FOR CLT

- ▶ Supports integration of NASA ATD-2 concept & technologies with FAA Surface CDM Concept of Operations
- ▶ Allows NASA to credibly test different options before finalizing concept of operations and exact configuration of different components of ATD-2
 - ▶ E.g., what is the best choice for the target departure queue length parameter for the departure metering component of ATD-2
- ▶ In future, this capability can be converted into a tactical what-if analysis tool for real-time departure planning
 - ▶ Part of ATD-2 real-time tactical what-if planning platform

PRESENTATION OUTLINE

- ▶ Solicitation Objective
- ▶ Evolution of Project Objectives
- ▶ **New Problem Definition—What-if Analysis**
 - ▶ ATD-2
 - ▶ Departure Metering Program (DMP)
 - ▶ What-if Analysis
- ▶ What-if Analysis Simulation Platform
- ▶ What-if Analysis Evaluations
- ▶ Conclusions and Discussion

ATD-2 OVERVIEW

- Scheduling of departures within a metroplex terminal environment to increase predictability, efficiency and throughput
 - Compute coordinated times for pushback, spot rendezvous, takeoff, departure fix crossing
 - Ideal departure profile: delay at gate, unimpeded taxi, continuous climb to cruise altitude

- Account for departure constraints
 - Merging at fixes and into overhead streams
 - Traffic Management Initiatives, weather impact on available fixes/routes
 - TMA Expected Departure Clearance
 - Arrival-departure flow interaction points on airport surface (e.g., shared runways, taxiways) and in terminal airspace

NASA Technologies	FAA Technologies
Terminal Sequencing and Spacing (TSS)	Time Based Flow Management (TBFM)
Precision Departure Release Capability (PDRC)	Terminal Flight Data Manager (TFDM)
Spot and Runway Departure Advisor (SARDA)	Traffic Flow Management System (TFMS)
Surface Decision Support System (SDSS)	

SURFACE COLLABORATIVE DECISION MAKING (CDM)

- ▶ Improve Shared Situational Awareness to Collaboratively Optimize Airport Capacity
- ▶ **Efficient Management of Departure Queues and Aircraft Flow on the Airport Surface**
- ▶ Improve Situational Awareness to Manage Arrival Traffic Flows
- ▶ Improve Analysis and Measurement of Surface Operations
- ▶ Global Harmonization
- ▶ Notifications

DEPARTURE METERING PROCEDURES (DMP)

- ▶ Target Movement Area entry Time (TMAT) for flights
 - ▶ Target Queue Length exceeds Upper Threshold
 - ▶ Metering times to maintain Target Queue Length

- ▶ Departure Reservoir Coordinator (DRC)
 - ▶ Actively monitor traffic for future demand-capacity imbalances (indicated by departure queue length)
 - ▶ Initiate departure metering based on the queue length predictions
 - ▶ Manage departure queue by setting the DMP parameter values

- ▶ What-if Modeling Automation
 - ▶ Determine DMP parameters in real-time
 - ▶ Determine the impact of DMP parameter changes
 - ▶ Share the results with other Stakeholders

DMP PARAMETERS

Parameter	Description
<ul style="list-style-type: none"> • Planning Horizon 	<ul style="list-style-type: none"> • Time within which flights expected to depart could be assigned metering times
<ul style="list-style-type: none"> • Departure Target Queue Length • Upper Threshold • Lower Threshold 	<ul style="list-style-type: none"> • Number of departures in the departure queue considered optimal for the local airport • Determine need for a DMP and reassignment of TMATs • Determine need for compression or termination of a DMP
<ul style="list-style-type: none"> • Unscheduled Demand Buffer • Lower Threshold • Upper Threshold 	<ul style="list-style-type: none"> • Number of unscheduled flights identified as potential demand • Unscheduled Flights Low notification • Unscheduled Flights High notification
<ul style="list-style-type: none"> • Airport Metering 	<ul style="list-style-type: none"> • Single airport queue or multiple runway queue metering
<ul style="list-style-type: none"> • TMAT Compliance Window 	<ul style="list-style-type: none"> • Window around the TMAT within which flights are considered compliant
<ul style="list-style-type: none"> • Others... 	

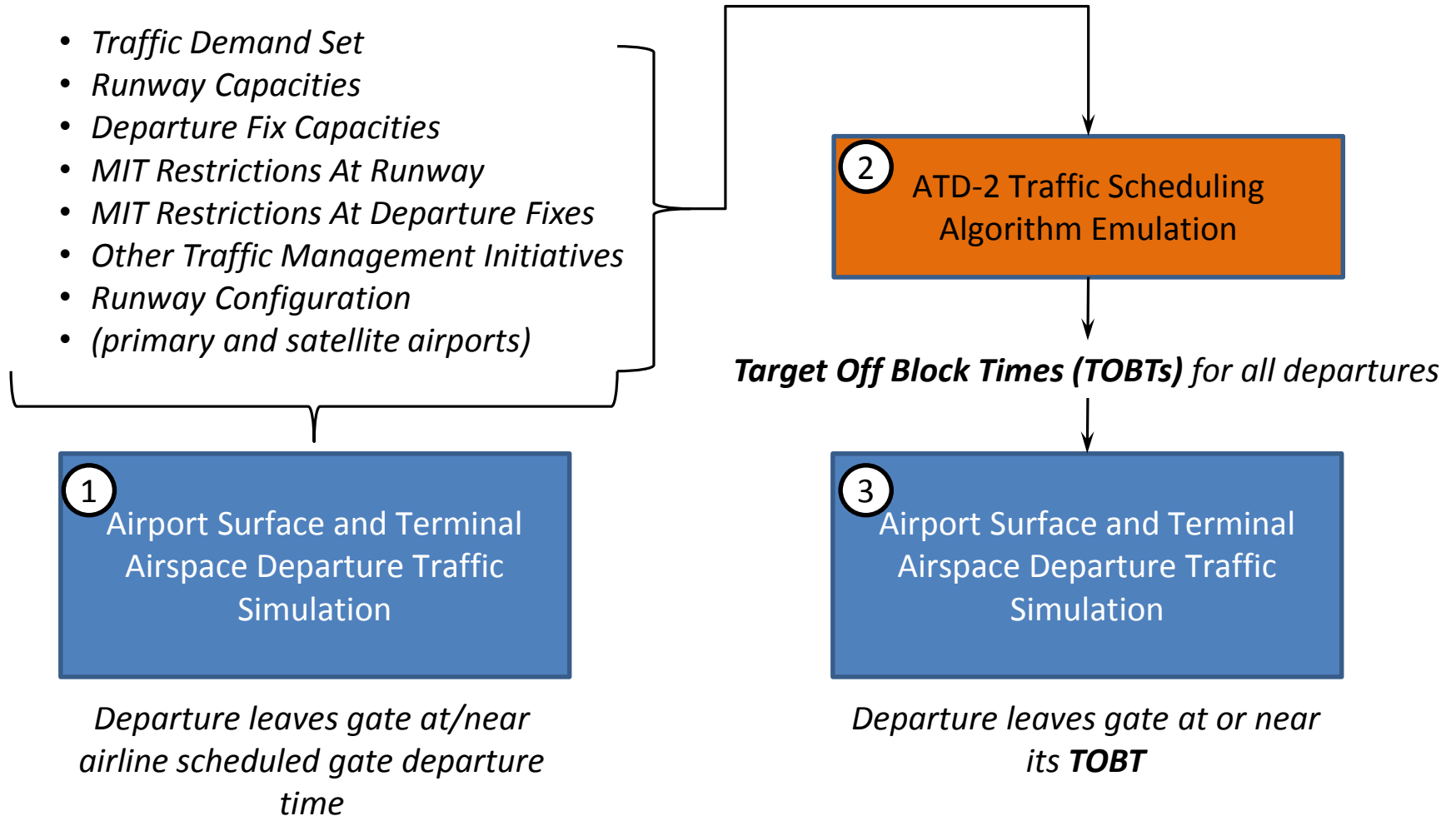
PRESENTATION OUTLINE

- ▶ Solicitation Objective
- ▶ Evolution of Project Objectives
- ▶ New Problem Definition—What-if Analysis
- ▶ **What-if Analysis Simulation Platform**
 - ▶ Components
 - ▶ How the simulation works
 - ▶ Airport surface/airspace adaptation
 - ▶ Departure scheduling
- ▶ What-if Analysis Evaluations
- ▶ Conclusions and Discussion

WHAT-IF ANALYSIS CAPABILITY OVERVIEW

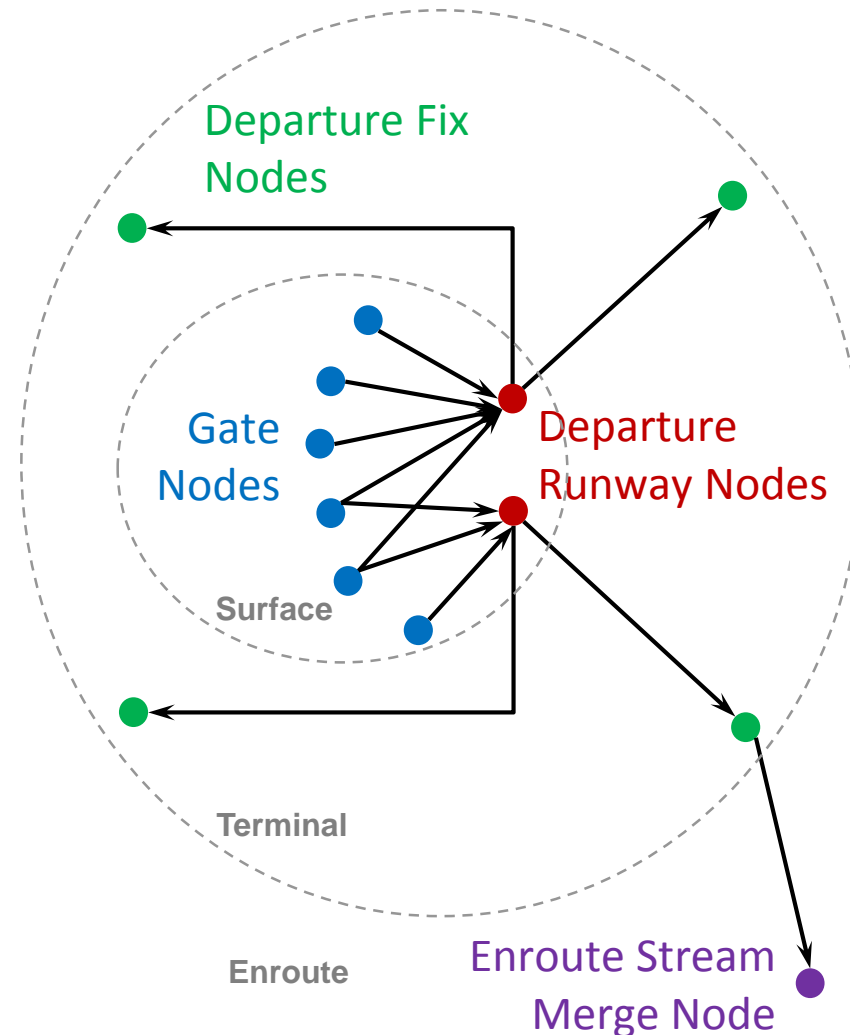
- ▶ Fast-time simulation
- ▶ Link-node model of the airport surface and terminal airspace routes
 - ▶ Primary and satellite airports within a metroplex
- ▶ Node queue control
 - ▶ Departure runways, departure fixes, and en route traffic stream merge-points
- ▶ Models current-day departure management
 - ▶ Sequencing for fix balancing, Approval Requests (APREQs), and miles-in-trail restrictions to constrained merge-fixes
- ▶ Alternatively models ATD-2 operations
 - ▶ Integrated surface-airspace traffic scheduling of Target Off Block Times (TOBTs) for departures to shift delays to the gates

WHAT-IF CAPABILITY COMPONENTS



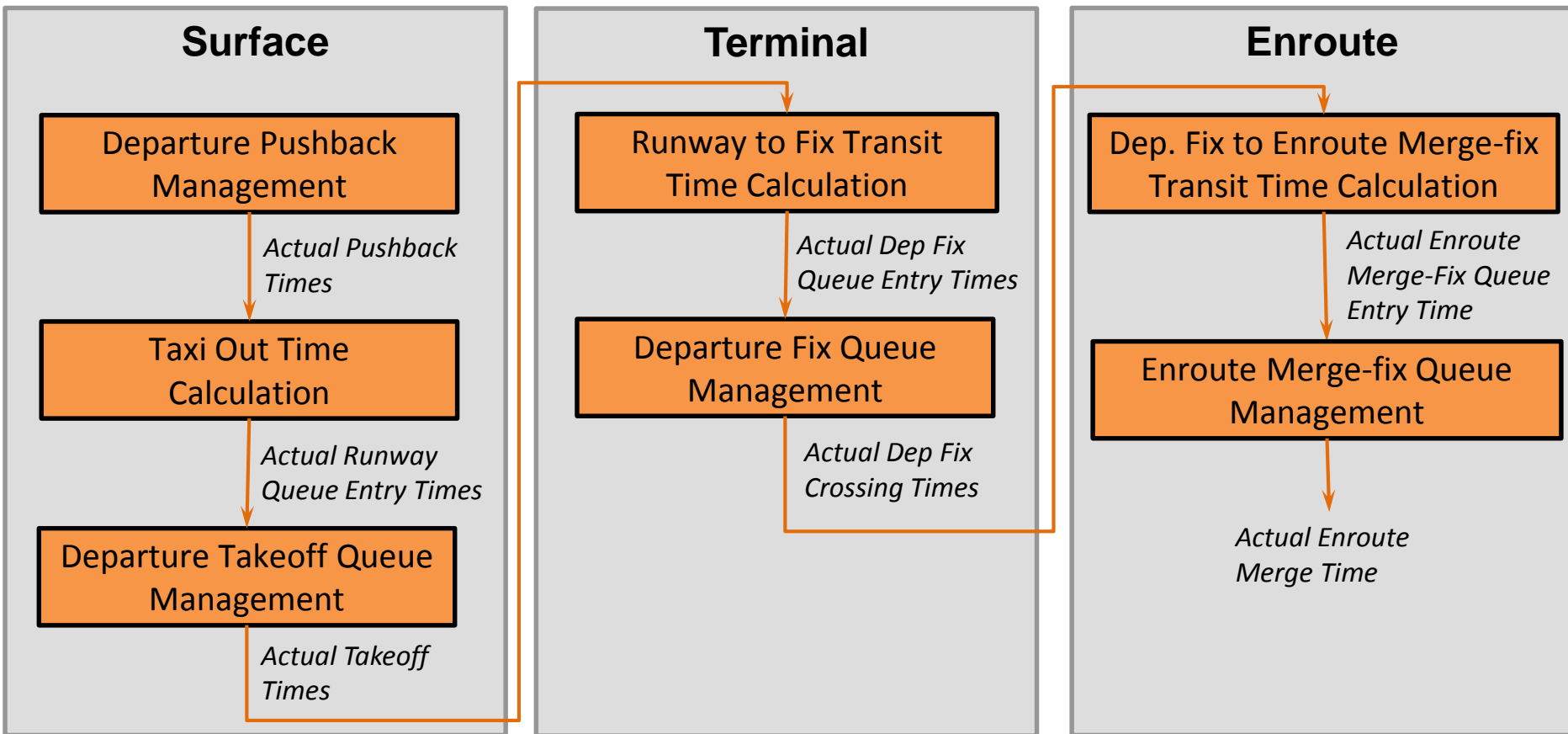
HOW THE SIMULATION WORKS (1)

- ▶ Link-node representation of airport surface, terminal airspace and en route airspace
- ▶ Queuing simulation with key control nodes located at
 - ▶ Terminal gate groups (by airline) at major and satellite airports
 - ▶ Departure runways at major and satellite airports
 - ▶ Departure fixes (metering fixes at the boundary of the TRACON)
 - ▶ Center-center boundary metering fixes (merge-fixes for the overhead enroute traffic stream)



HOW THE SIMULATION WORKS (2)

- ▶ Transit time & queue management models on airport surface, terminal airspace and enroute airspace



ADAPTATION TO CHARLOTTE METROPLEX

Parameter	Source
Interacting satellite airports	<ul style="list-style-type: none"> • Concord Regional (JQF), Charlotte-Monroe Executive (EQY), Spartanburg Downtown Memorial (SPA), Hickory Regional (HKY), Gasontia Municipal (AKH), Rock Hill (UZA) and Statesville Regional (SVH) • Based on FAA Optimization of Airspace and Procedures in the Metroplex (OAPM) Study Reports
Runways	<ul style="list-style-type: none"> • Lumped capacity model for CLT & satellite airports
Taxi times	<ul style="list-style-type: none"> • Airline-specific ASQP model for CLT, fixed model for satellites
Departure fixes	<ul style="list-style-type: none"> • ANDYS, BUCKL, DEBIE, GANTS, JACAL, LILLS, MERIL, SPA, SUG, ZAVER • Identified from CLT Standard Instrument Departure (SID) procedures and departure fixes for flights in SOSS input file • Assigned based on departure fix closest in bearing to destination airport
En route merge points	<ul style="list-style-type: none"> • PSEUDO_15MIN_FROM_DF for flights via departure fix MERIL
Airborne transit times	<ul style="list-style-type: none"> • Simple & Boeing physics-based models

DEPARTURE TRAJECTORY MODEL

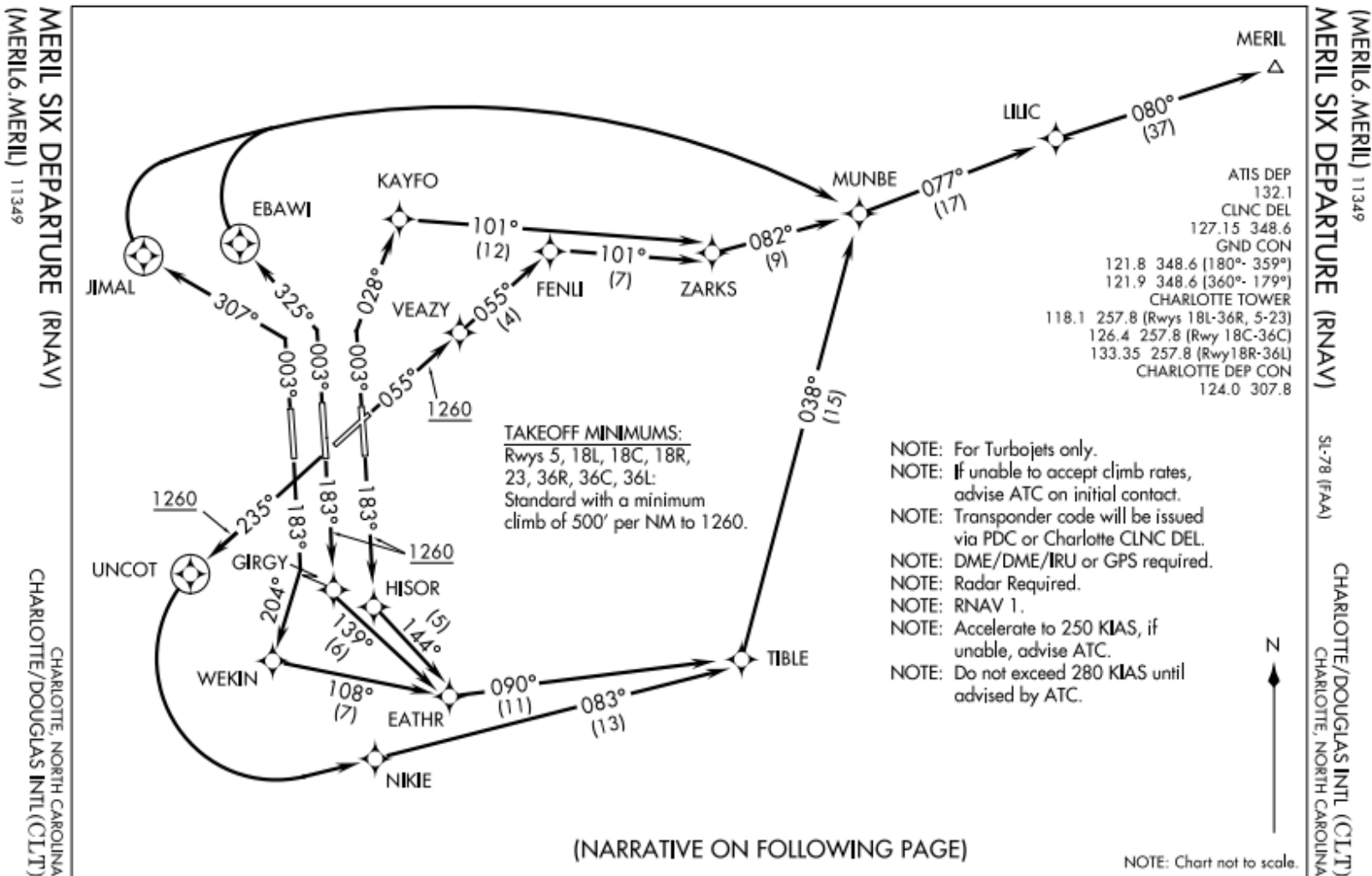
- ▶ 737 NG Test Bench at Boeing Integrated Aircraft Simulation Laboratory (IASL) was utilized to perform a multitude of real-time departure simulations (MERIL7 – Charlotte)
 - ▶ 737 Flight software and hardware working in closed-loop with high fidelity aircraft and environmental models
 - ▶ Obtained accurate aircraft state data versus time over 94 separate permutations of departure conditions from initial runway departure through achievement of cruise altitude at 35,000 ft.
 - ▶ time, altitude, calibrated airspeed, ground speed, rate-of-climb, fuel burn, ...
 - ▶ data above delivered at each major waypoint (and archived at 1 sec intervals)
 - ▶ Able to see trends in the data for transit time and fuel usage variations to assist in the overall objectives of this NRA study

- ▶ Hardware and software contained within this simulation framework enable some of the highest fidelity results on the performance of aircraft trajectory and state data time histories for test and evaluation of scenarios, but limited to real-time operations.

- ▶ Fast-time medium fidelity aircraft simulations can be utilized for future studies of this nature that will produce acceptable levels of accuracy

MERIL6/7 DEPARTURE PROCEDURE

SE-2, 28 MAY 2015 to 25 JUN 2015



SE-2, 28 MAY 2015 to 25 JUN 2015

DEPARTURE PROCEDURE / GENERAL TRENDS

- ▶ Two overlapping MERIL Routes were simulated
 - ▶ RW18L through HISOR, EATHR, TIBLE, MUNBE, LILIC, MERIL
 - ▶ RW18R through WEKIN, EATHR, TIBLE, MUNBE, LILIC, MERIL
 - ▶ Modified CDU “Legs” pages during simulation pre-flight procedures to affect routing changes

- ▶ Simulation of these two routes with superimposed variations on aircraft initial conditions
 - ▶ Varied aircraft initial take-off weights (minimum, medium and maximum 737-700 aircraft weights)
 - ▶ Varied powered flight cost index values entered into CDU (0, 250 and 500)
 - ▶ Varied initial ground temperatures (affecting air densities and thus lift characteristics in early flight)
 - ▶ Wind variations (no wind, a forecast wind, a deviation of the forecast wind)

- ▶ Higher cost indices (i.e., 500) cause aircraft FM logic to burn fuel faster and arrive at given respective waypoint destinations in shorter intervals of time

- ▶ Superimposed weight variations show some transit time variability, with higher weight aircraft tending to arrive at destinations later, but with less of an impact on performance when compared to cost index variations

- ▶ Modest (realistic) wind variations empirically show lower levels of transit time influence, given the conjecture that powered flight during the departure phase likely overwhelms these wind differences.

EXAMPLE AIRCRAFT STATE DATA AT WAYPOINTS FOR ONE CASE

Case: 133 klbs (medium Wt); Cost Index=500; rw18L; 10min Level Off

	Time (sec)	Altitude (ft)	CAS (knots)	Ground Speed (knots)	Fuel Burn (lbs)	Ground Distance (nmi)	Flight path Angle (deg)	Rate of Climb (ft/sec)
HISOR	115.0	4087.7	168.5	177.0	526.	3.9	8.0	42.1
EATHR	224.7	7994.5 (in level)	254.3	285.0	955.6	11.3	0.38	3.2
TIBLE	357.0	8004.5 (in level)	248.2	278.3	1140.7	21.5	-0.11	-0.9
MUNBE	548.8	7999.3 (in level)	249.7	279.9	1407.3	36.3	-0.12	-1.0
LILIC	764.8	11106.3	298.6	349.1	1910.9	53.6	1.5	15.3
MERIL	1079.1	23393.6	334.3	465.2	3028.4	90.6	2.06	28.3

EMULATION OF ATD-2 DEPARTURE SCHEDULING

- ▶ ATD2 scheduler computes Target Off Block Times (TOBTs) for departure flights in order to
 - ▶ Absorb most delays at the gate
 - ▶ Enable departure flights to fit into available slots at the runway, with minimum taxi delays
 - ▶ Orchestrate the merging of departures from multiple airports to commonly shared departure fixes with minimum possible airborne delays
 - ▶ Coordinate takeoff times of departures to “hit” enroute merge stream gaps

- ▶ Predict unimpeded times to the runway, departure-fix and enroute stream merge point

- ▶ Determine earliest runway departure times
 - ▶ Adhere to ration-by-schedule principle
 - ▶ Space flights sufficiently at the runway
 - ▶ Delay runway departure time to “hit” enroute merge stream gaps

- ▶ Apply Order of Consideration algorithm to determine sequence of departure-fix merging, back propagating delay to the surface
 - ▶ Emulate TMA’s Dynamic Planner algorithm

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- ▶ **What-if Analysis Evaluations**
 - ▶ DMP Start & End Times
 - ▶ DMP Target Departure Queue Length
 - ▶ DMP Unscheduled Demand Buffer
- ▶ Conclusions and Discussion

WHAT-IF ANALYSIS USE CASES

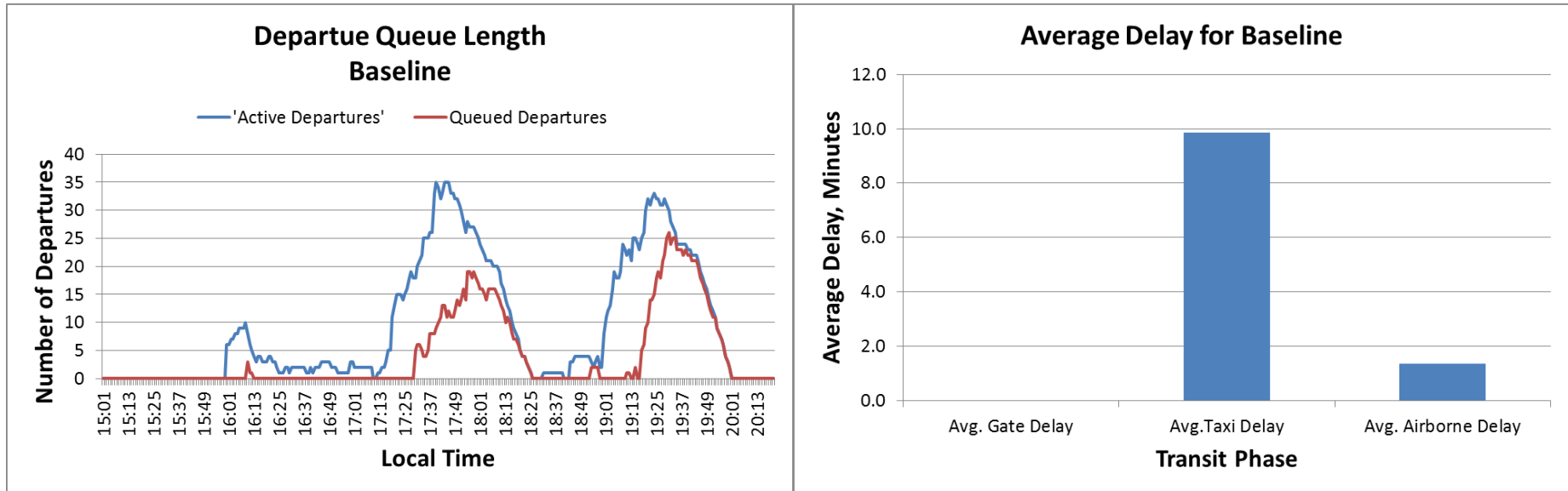
Defined three Use Cases (UCs) based on hypothesized DRC activities:

- ▶ UC1: DMP Start and End Times
 - ▶ DRC assesses candidate DMP start and end times, selects values
 - ▶ Time period for ATD2 scheduling of departure flight TOBTs/TMATs, accounting for all other traffic

- ▶ UC2: Target Departure Queue Length (TDQL) (and Upper/Lower Bounds)
 - ▶ Given DMP start and end times, DRC assesses candidate departure queue lengths, selects value
 - ▶ TDQL of X: number of minutes of departure delay shifted from gate holding to taxiing during DMP
 - ▶ Departure queue slot = runway time-slot, ~1 minute
 - ▶ Hasten TBOT or TMAT

- ▶ UC3: Unscheduled Demand Buffer
 - ▶ Given DMP start and end times and TDQL, DRC assesses candidate capacity allocations for unscheduled demand
 - ▶ Reduce airport departure quarterly capacity during DMP to accommodate unscheduled traffic

BASELINE PERFORMANCE

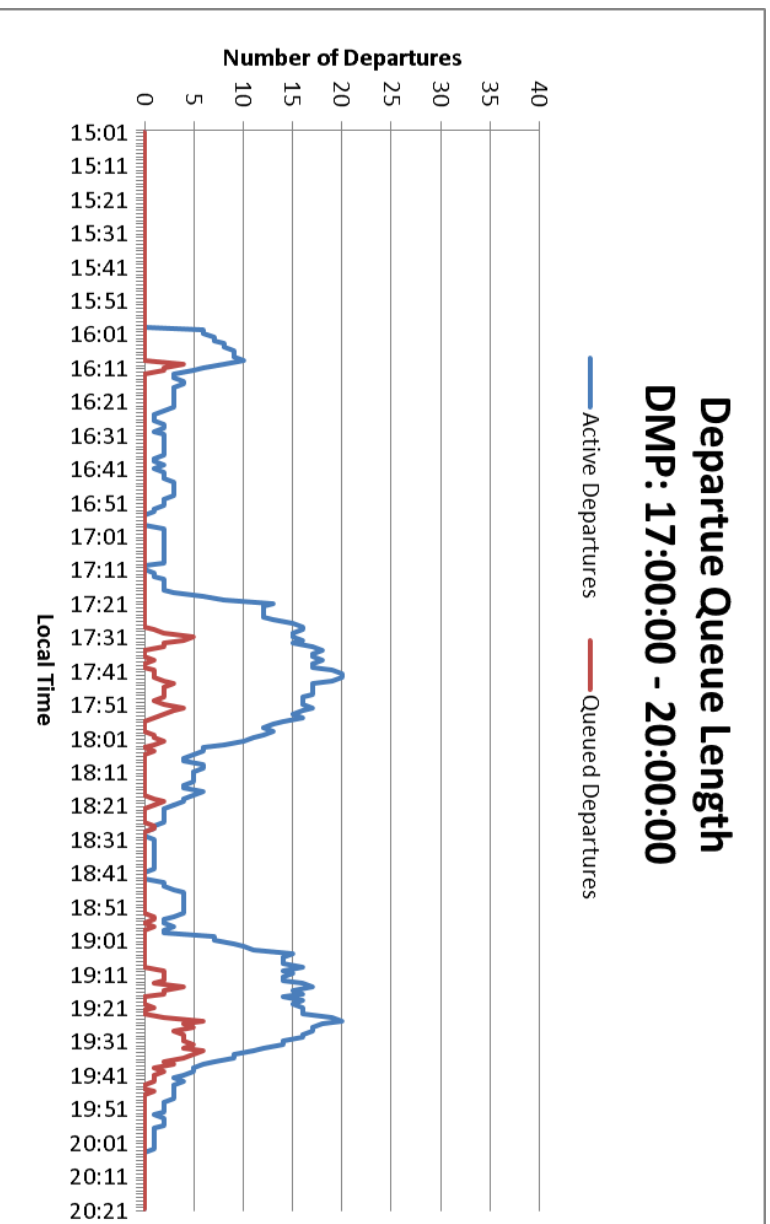


- ▶ Two departure demand peaks, 17:00 – 20:00
 - ▶ Active departures exceeds 15 in 1-minute period
 - ▶ Runway queue exceeds 15 in 1-minute period
- ▶ Options: 1 longer DMP, 2 short DMPs or other...
 - ▶ Consider operational complexity, other constraints besides target departure queue length alone in specification

UC1: START & END TIME SELECTION

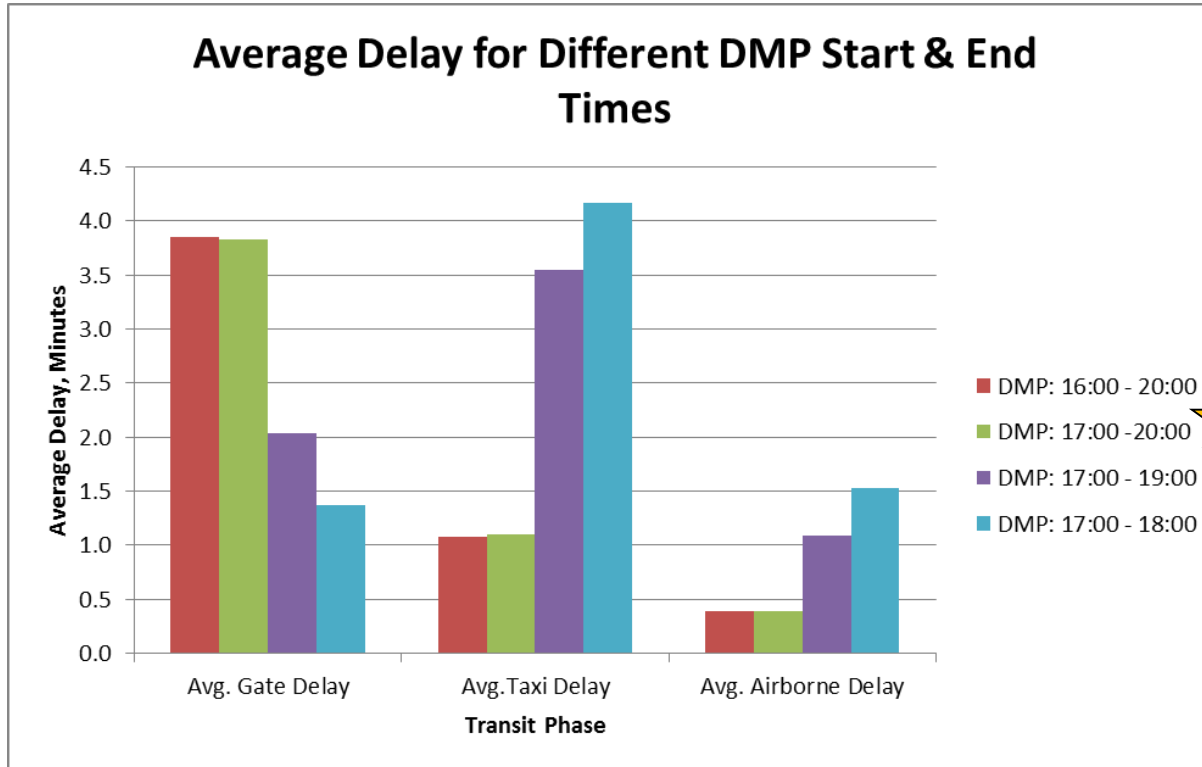
- ▶ Maintain number of active departures to acceptable level, e.g., 15
- ▶ Maintain gate delay to a level acceptable with occupancy considerations for airlines
- ▶ Minimize taxi delay to extent possible
- ▶ Maintain airport departure throughput

USE CASE 1: START & END TIMES



- Evaluated 16:00-20:00, 17:00-20:00, 17:00-19:00, 17:00-18:00
- Selected 17:00-20:00 to minimize duration of DMP while meeting acceptable number of active departures and maintaining departure throughput

USE CASE 1: START & END TIMES

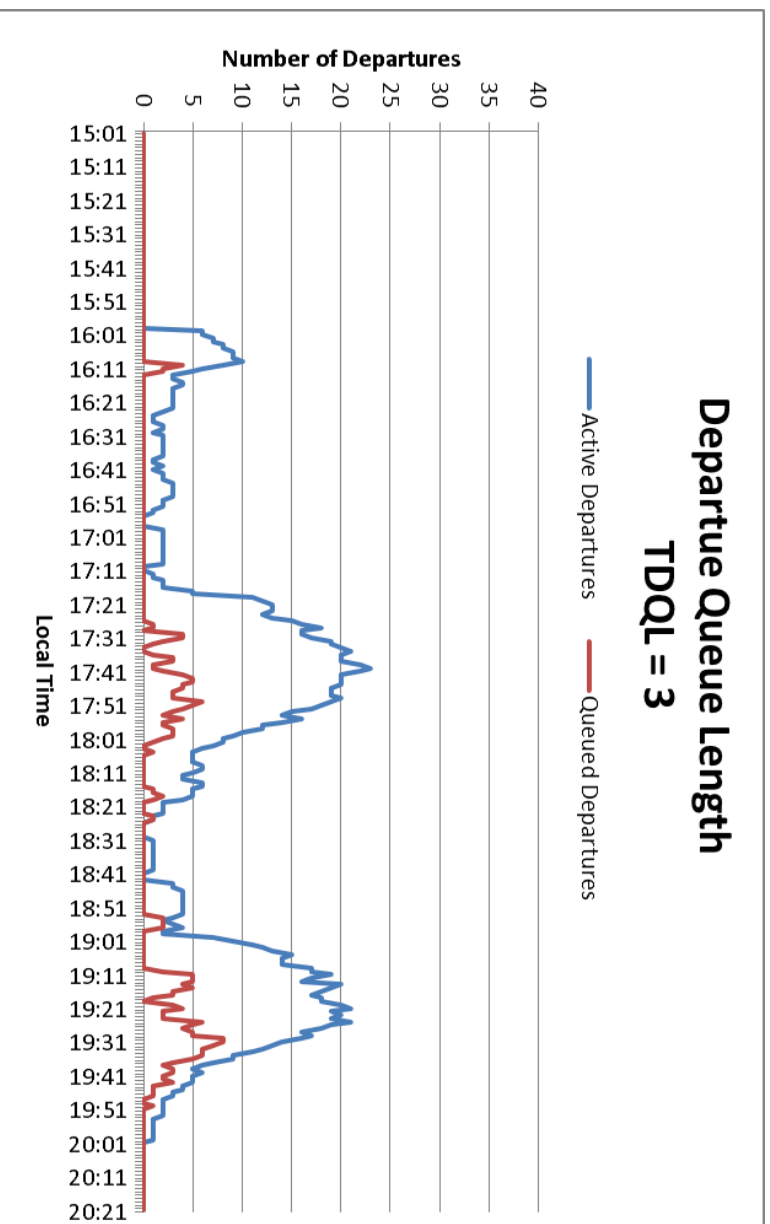


- Departure scheduling shifts taxi & airborne delay to gate
- DMP start & end times impact distribution of delay among gate, taxi, airborne flight phases

USE CASE 2: TARGET DEPARTURE QUEUE LENGTH

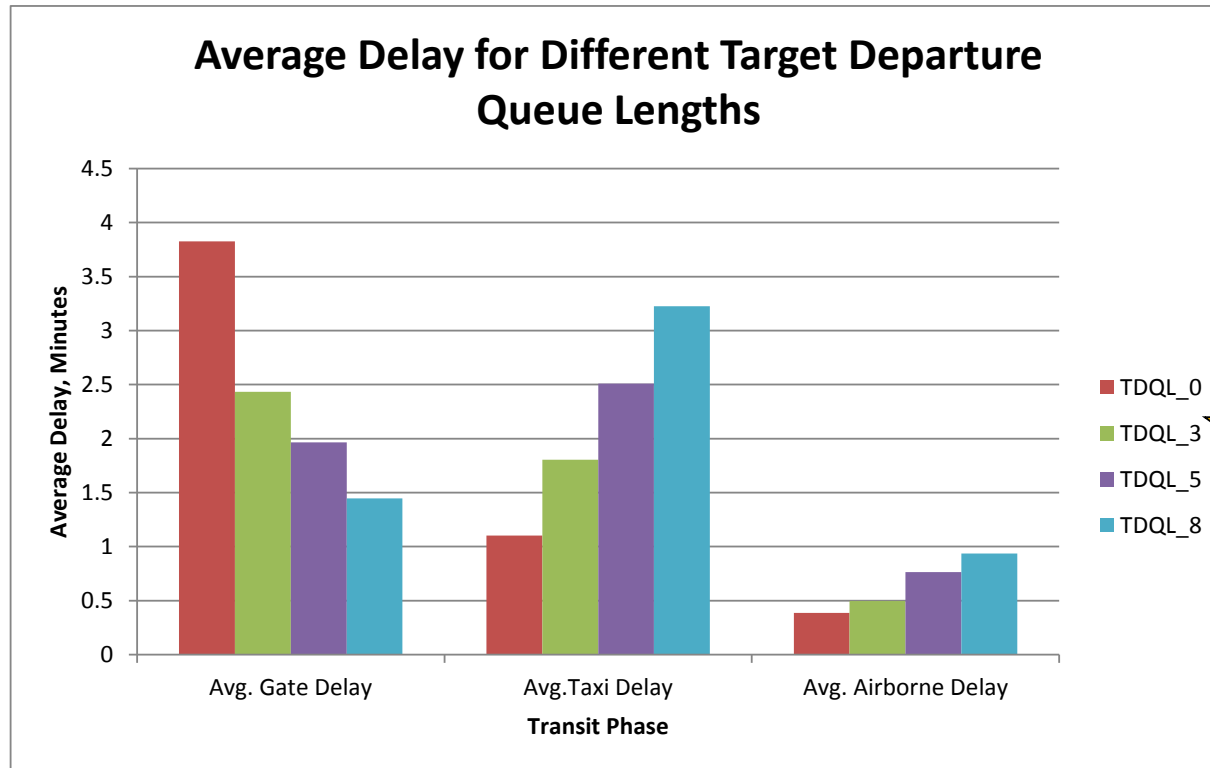
- ▶ Avoid starving the runway of flights while there are active departures
- ▶ Maintain number of active departures to an acceptable level

USE CASE 2: TARGET DEPARTURE QUEUE LENGTH



- Evaluated Target Departure Queue Lengths of 0, 3, 5, 8 minutes of delay apportioned to taxi transit from gate holding
- Selected 3 to maximize departure throughput while meeting acceptable number of active departures

USE CASE 2: TDQL SELECTION

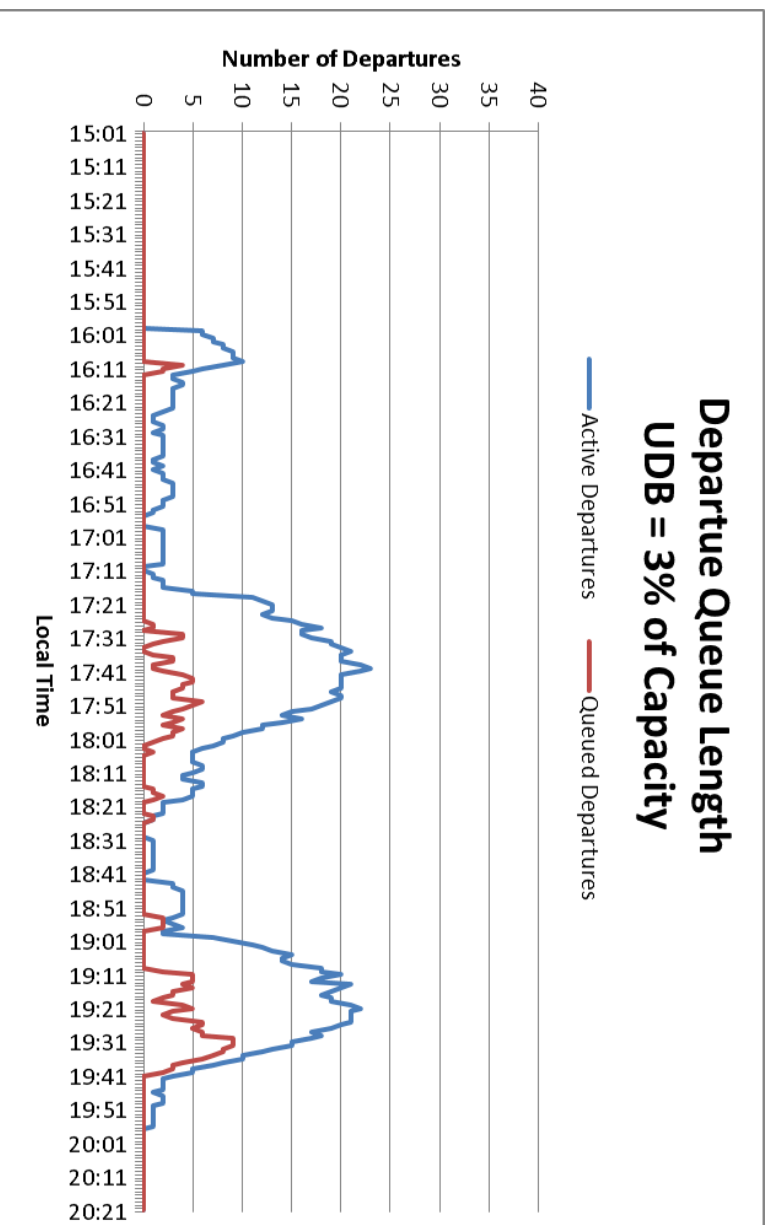


- TDQL shifts gate delay to taxi & airborne phases
- Selected 3 to retain gate holding benefits while meeting acceptable number of active departures

USE CASE 3: UNSCHEDULED DEMAND BUFFER

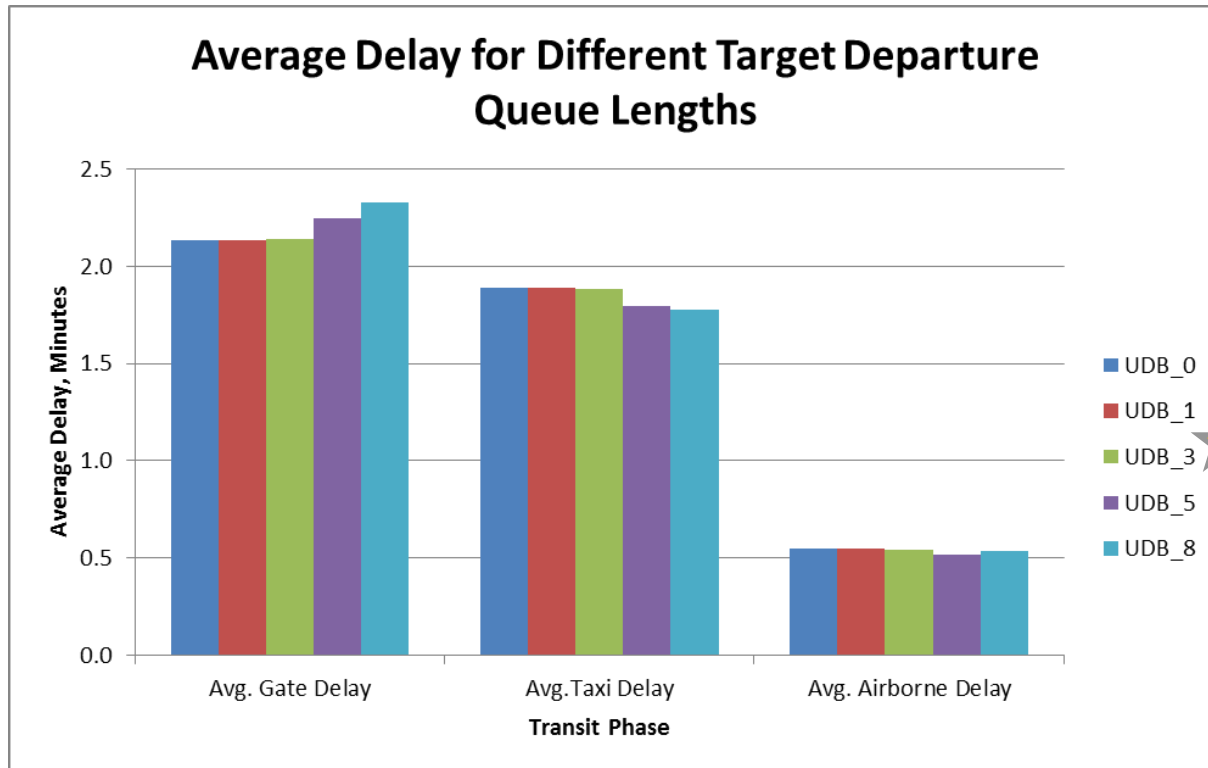
- ▶ At lower levels, UDB has minimal impact on departure queues and taxi delays
- ▶ May be more appropriate to specify this parameter a priori based on typical unscheduled demand levels and apply to DMP rather than design on the fly

USE CASE 3: UNSCHEDULED DEMAND BUFFER



- Evaluated Unscheduled Demand Buffers of 1, 3, 5, 8% of departure capacity
- Selected 3 to afford as much departure capacity as possible without increasing delay

USE CASE 3: UNSCHEDULED DEMAND BUFFER

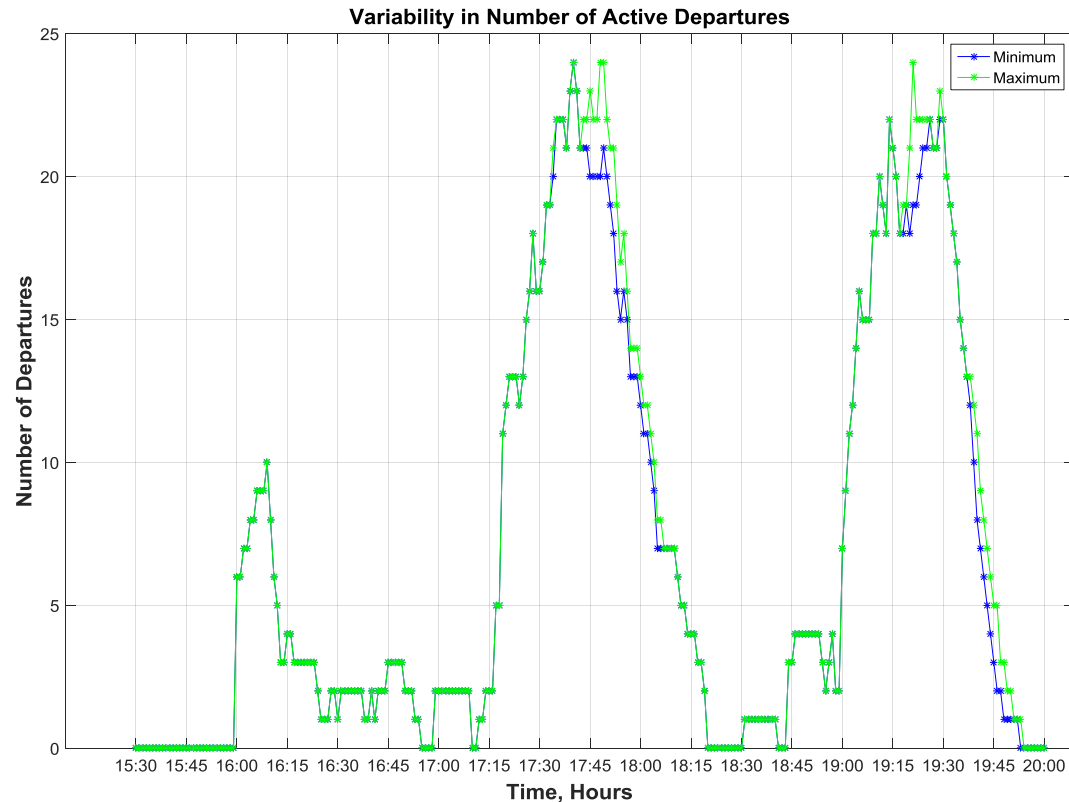


- UDB has minimal impact on transit delay at low buffer levels
- Select value which maintains gate delay

IMPACT OF UNCERTAINTY

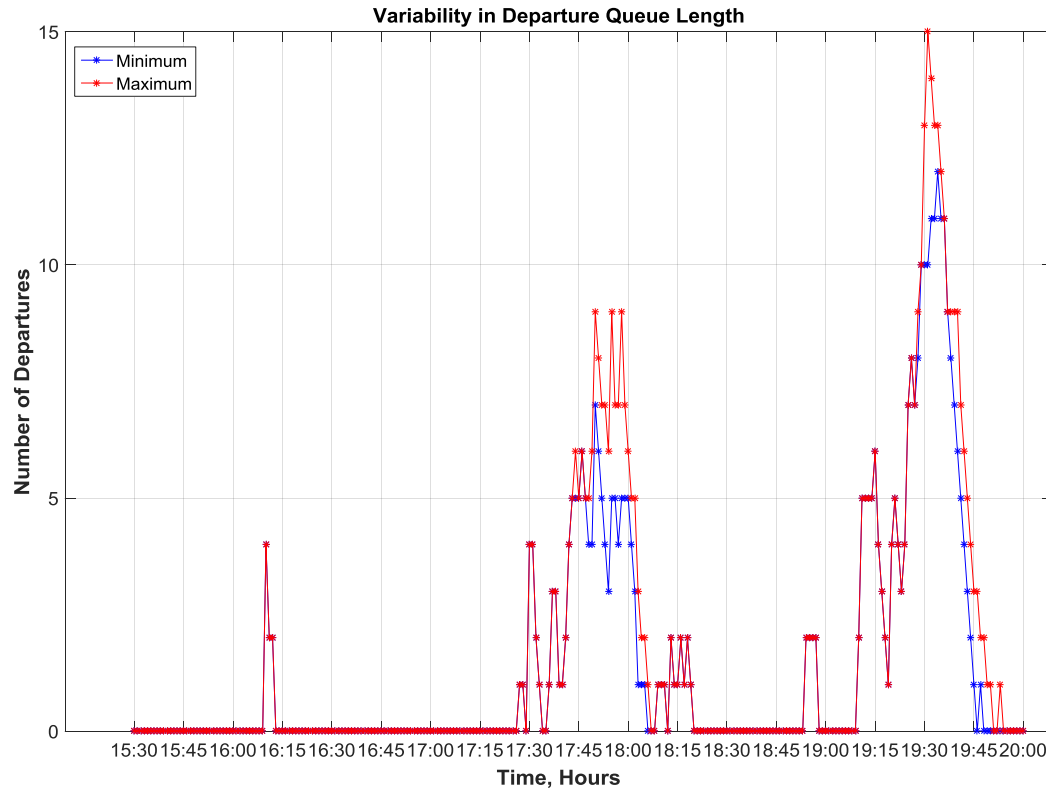
- ▶ Initial evaluation of the impact of transit time uncertainty on effectiveness of DMP
 - ▶ Incorporate transit time uncertainty models into CLT surface traffic simulation, conduct 100 simulation runs
 - ▶ Evaluate resulting performance of airport surface traffic under specified DMP parameters
- ▶ Data sources
 - ▶ Taxi transit time
 - ▶ Airline-specific ASQP taxi-time data for CLT up to 10th percentile
 - ▶ Terminal airspace transit time
 - ▶ Adapt & apply data from Boeing simulations of MERIL7 SID
 - ▶ En route airspace transit
 - ▶ 10-minute mean transit time, standard deviation based on Boeing terminal airspace transit data
 - ▶ Assume each is Normally distributed as per mean and standard deviation for each

NUMBER OF DEPARTURES



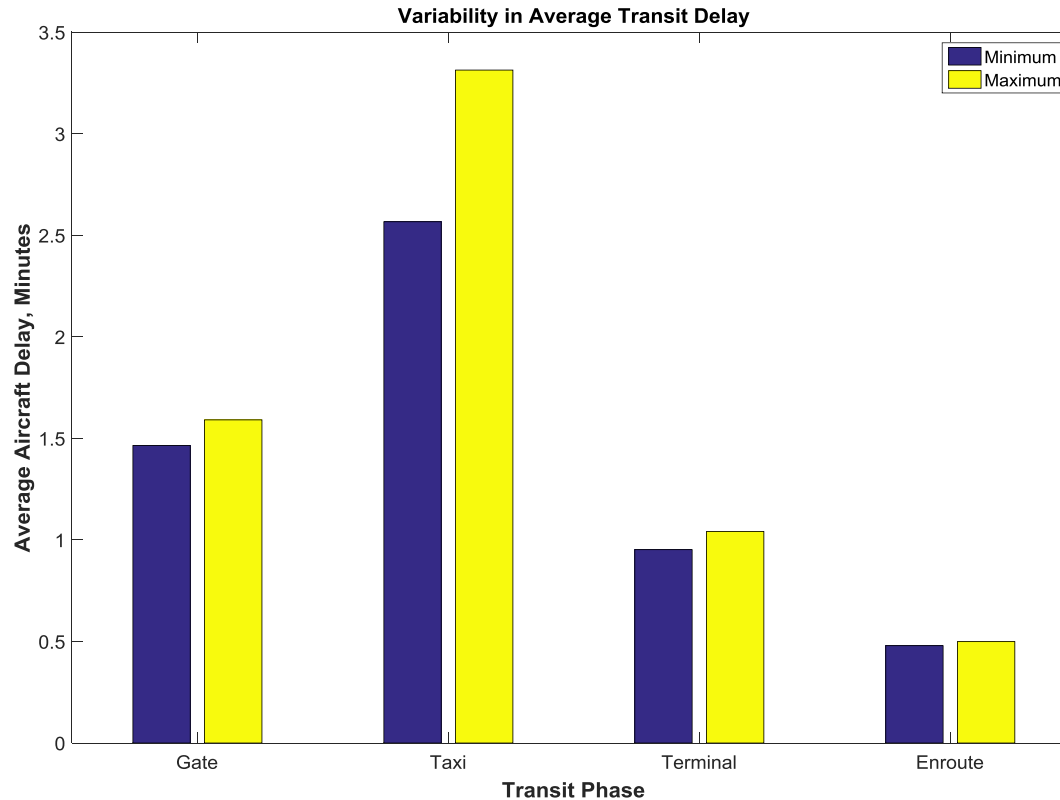
- Modest range of number of aircraft on the airport surface with differences of ~3-5 aircraft during peak demand periods

DEPARTURE QUEUE LENGTH



- Modest range of the number of aircraft in the departure queue with differences of ~2-5 aircraft during peak demand periods

AVERAGE DELAY BY FLIGHT PHASE



- Modest range of taxi delays experienced with differences of ~1.0 minutes in mean taxi delay of aircraft

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CONCLUSIONS & DISCUSSION

- ▶ Evaluation of the What-if Analysis capability indicates the potential to improve the DMP parameter selection process

- ▶ Use Case Evaluation
 - ▶ Number of flights in the ramp + movement area is a key control parameter
 - ▶ Above N is a good indicator of when to start a DMP
 - ▶ Below N is a good indicator of when to end a DMP

 - ▶ May not be possible to precisely control the departure queue length, but TDQL is effective in tuning departure throughput

 - ▶ The unscheduled demand buffer may not have any positive effect without an estimate of when unscheduled flights might appear

 - ▶ Transit time uncertainties introduce some variability in the surface traffic levels and flight delays realized with a DMP

BACKUP

LITERATURE REVIEW

- ▶ Focus on precision methods of arrival and departure management in the terminal area

- ▶ Summary of literature in areas including
 - ▶ scheduling concepts
 - ▶ schedule conformance
 - ▶ off-nominal situations
 - ▶ evaluations of tools and gaps identified
 - ▶ technological requirements for tools
 - ▶ management of arrival-departure interactions
 - ▶ airport surface traffic management
 - ▶ metroplex operations

REAL-WORLD PROBLEM SELECTION

- ▶ Select five high-priority arrival-departure interactions from metroplex or single-airport sites

- ▶ Literature review, subject matter expert consultation, data analysis to identify & evaluate

- ▶ Compared & selected sites via numerous factors
 - ▶ Presence of significant departure delays
 - ▶ Presence of significant arrival delays
 - ▶ Dependent runway usage
 - ▶ Problem site in the FAA FACT-2 Report
 - ▶ Complexity of arrival-departure TRACON airspace
 - ▶ Others

REAL-WORLD PROBLEM SITES

Site	Reason for Selecting
New York metropolx	High departure and arrival delays at all component airports; highly complex terminal airspace; multiple runway interaction geometry-types present at different metropolx airports; interest from NASA; SMEs identified multiple existing problems that can be solved by tactical scheduling decision support tools
Charlotte International Airport	High departure delays; significant potential for saving departure delays by better traffic management; intersecting arrival-departure runways; multiple points where taxiing aircraft cross active arrival and departure runways; restricted ramp area causing arrival-departure interactions; presence of interactions between departure flows and overhead en route streams; interest from NASA; SMEs identified airspace interaction problems that can be solved by strategic/tactical temporal scheduling
Southern California metropolx	Presence of significant departure delay, mixed-use runway at LAX, limited space for building queues to hold aircraft while they wait to cross active runways identified as a major problem; SMEs identified number of high-priority terminal airspace interactions that may be resolved by strategic or temporal trajectory control methods
Atlanta Hartsfield International Airport	High departure delays; significant potential for saving departure delays by better departure management; two closely spaced parallel runway pairs, frequently used for simultaneous arrival and departure operations
Northern California metropolx	Three airports within close proximity display multiple interdependencies, intersecting runway pairs at SFO create a unique scheduling problem, limited space for building queues to hold aircraft while they wait to cross active runways identified as a problem

REAL-WORLD PROBLEMS PROPOSED

Problem	Description
1) JFK 22R departures interacting with JFK 22L/22R arrivals	JFK 22R departures tunnel under the JFK 22L/22R arrivals at 5000 feet for 20-25 miles
2) JFK Arrivals on VOR 13L, interact with LGA 13 ILS arrivals and LGA 13 departures	Indirect routing of LGA 13 departures to avoid JFK 13L arrivals via VOR approach using Coney airspace; significant source of delay
3) EWR Arr-22L, Dep-22R; TEB Dep-19: TEB departures interact with EWR arrivals	TEB 19 departures via noise abatement procedure require 10 MIT gaps in EWR 22L arrivals
4) CLT runway operations—integrated arrival-departure-surface interaction	18C arrivals & departures, 18L & 18C departures with 23 arrivals, 18R arrivals crossing 18C departures & arrivals, call for release of departures
5) LAX runway system interactions	Arrivals to outboard runways crossing inboard departure runways, mixed-use of inboard runways

AIRPORT SURFACE/TERMINAL AIRSPACE ADAPTATION

- ▶ Interacting satellite airports
 - ▶ Identified from FAA Optimization of Airspace and Procedures in the Metroplex (OAPM) Study Reports

- ▶ Departure fix & enroute merge point locations
 - ▶ Based on CLT Standard Instrument Departure (SID) procedures and departure fixes for flights in SOSS input file

- ▶ Departure fix/runway assignment
 - ▶ Based on actual assignment data where available
 - ▶ Otherwise, assign flight to departure fix closest in bearing to destination airport, relative to origin airport
 - ▶ Runway assignment based on departure fix

- ▶ Taxi Times
 - ▶ Unimpeded times based on ASQP taxi time data

- ▶ Airborne transit times
 - ▶ Physics based model: Simple Model, Boeing Model

SIMULATION CONTROLS AND EVALUATION METRICS

- ▶ Calculations within simulated traffic management DSTs are controlled by the parameters such as Target Departure Queue Length, Static Time Horizon, etc.

- ▶ What-if analysis capability allows fast evaluations over different values of individual parameters and combinations
 - ▶ Manual mode: Test performance at a few user-defined points in the parameter space
 - ▶ Auto mode: Sweep over a range of parameter values

- ▶ Key metrics are computed by simulating traffic over a user-defined time-horizon for each combination of parameter settings

- ▶ Metrics are displayed on a succinct display that is easy for a Departure Reservoir Coordinator (DRC) to comprehend quickly and make informed decisions

UC1: DMP START AND END TIMES

- ▶ DRC determines start and end times of DMP
 - ▶ Detects demand-capacity imbalance for runways
 - ▶ Baseline simulations
 - ▶ Analyzes Departure Queue Graph, Departure Fix Load Graph, Enroute Merge Point Load Graph
 - ▶ Determines candidate start/end times to evaluate
 - ▶ Selection criteria
 - ▶ Conducts what-if analysis for discrete start/end time combinations
 - ▶ ATD-2 scheduling and simulations
 - ▶ Selects discrete start/end times based on airport traffic performance criteria
 - ▶ Start/end times to 15-minute precision, similar to JFK DMAN

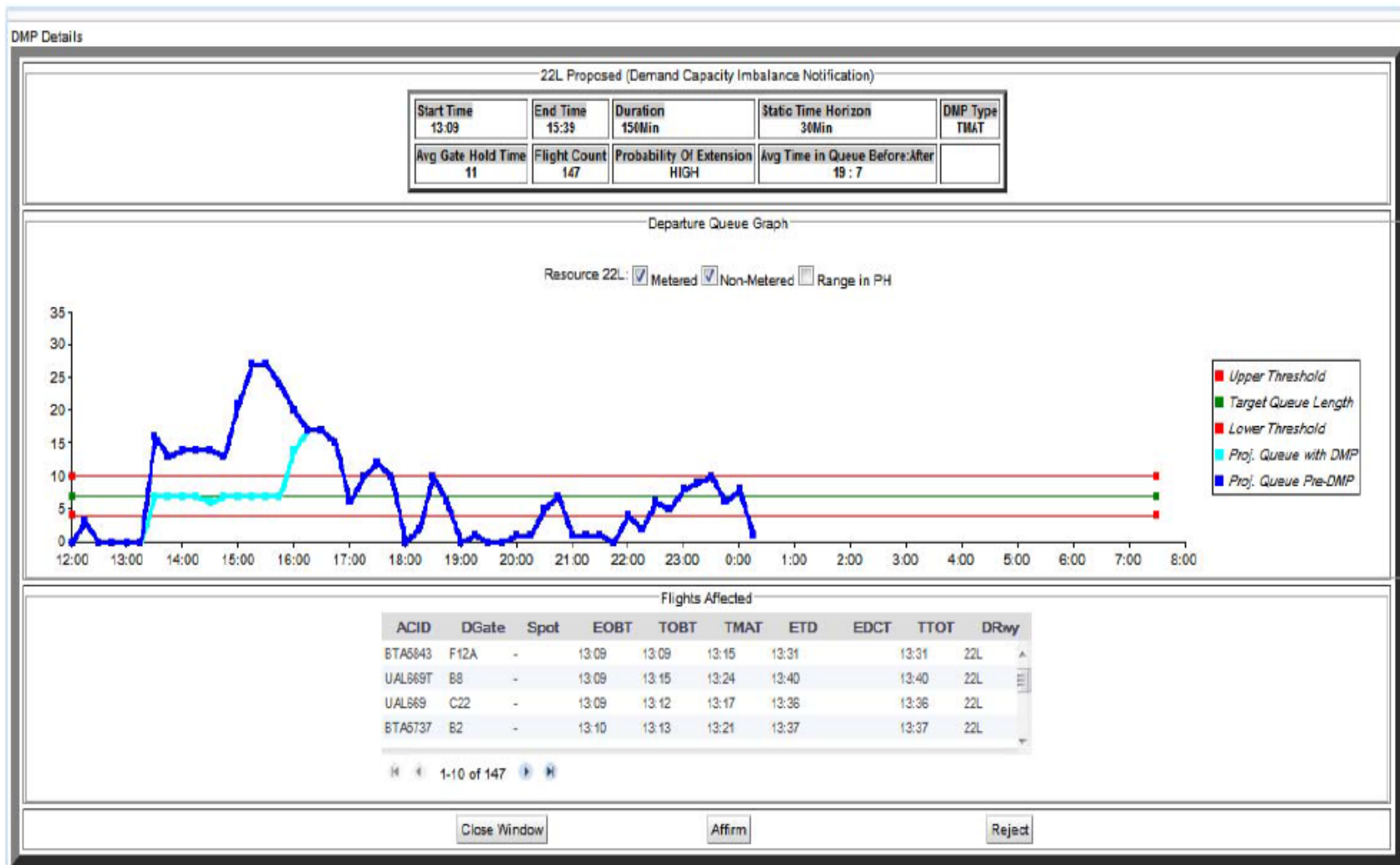
UC2: TARGET DEPARTURE QUEUE LENGTH (TDQL) AND UPPER/LOWER BOUNDS

- ▶ DRC determines the TDQL and its upper/lower bounds, airport-wide or per-runway
 - ▶ DMP start and end times established
 - ▶ Determines candidate TDQL and bounds to test
 - ▶ Conducts what-if analysis for discrete TDQL and upper/lower bound values
 - ▶ ATD-2 scheduling and simulations
 - ▶ Selects TDQL and upper/lower bound values based on airport traffic performance criteria
 - ▶ ATD-2 performance evaluation
 - ▶ Selects policy to manage event of excessive mismatch between actual and target departure queue length
 - ▶ ATD-2 performance evaluation

UC3: UNSCHEDULED DEMAND BUFFER

- ▶ DRC determines Unscheduled Demand Buffer (UDB) of DMP
 - ▶ DMP start and end times, TDQL and upper/lower bounds established
 - ▶ Determines individual or range of UDB values to test
 - ▶ Conducts what-if analysis for discrete UDB values
 - ▶ Selects UDB values based on airport traffic performance criteria
 - ▶ ATD-2 performance evaluation

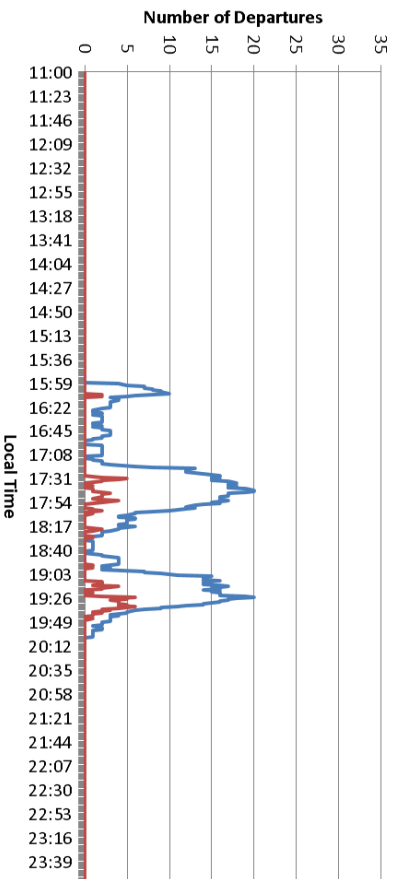
DEPARTURE METERING PROGRAM



UC1: DMP START & END TIMES

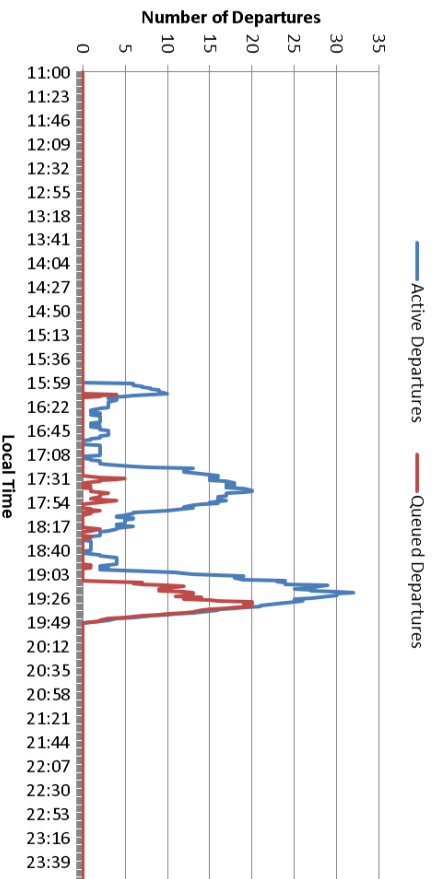
Departure Queue Length

DMP: 16:00:00 - 20:00:00



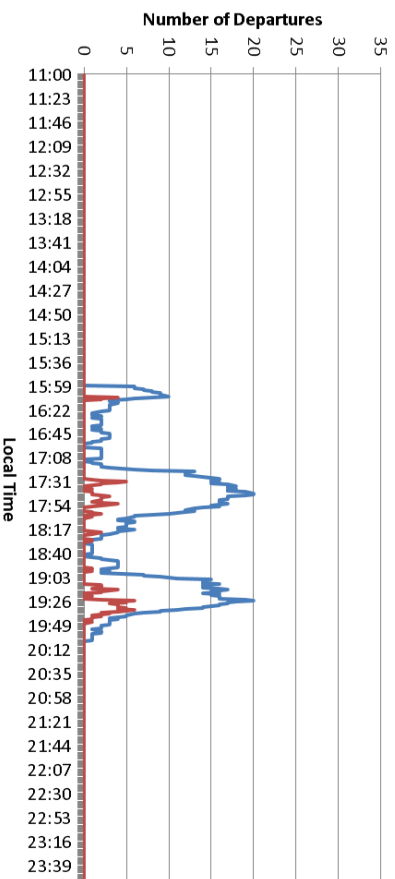
Departure Queue Length

DMP: 17:00:00 - 19:00:00



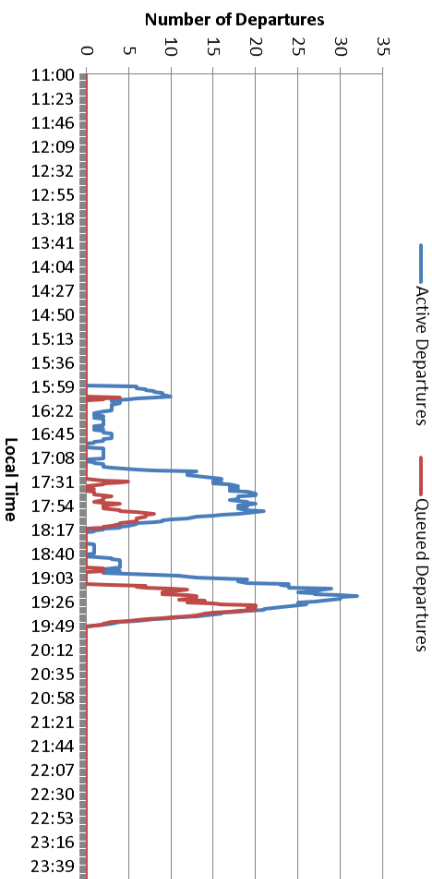
Departure Queue Length

DMP: 17:00:00 - 20:00:00



Departure Queue Length

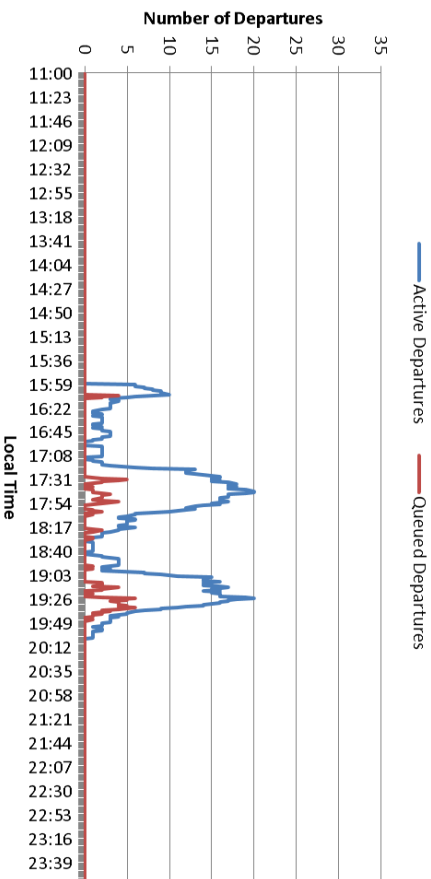
DMP: 17:00:00 - 18:00:00



UC2: TDQL SELECTION

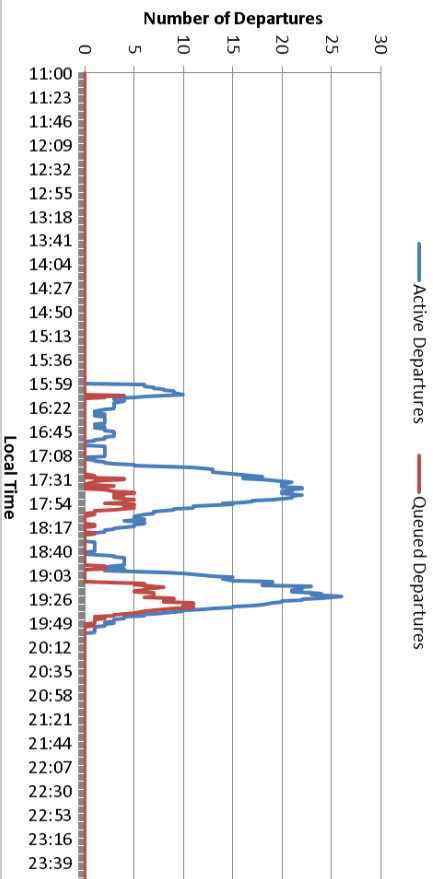
Departure Queue Length

TDQL = 0



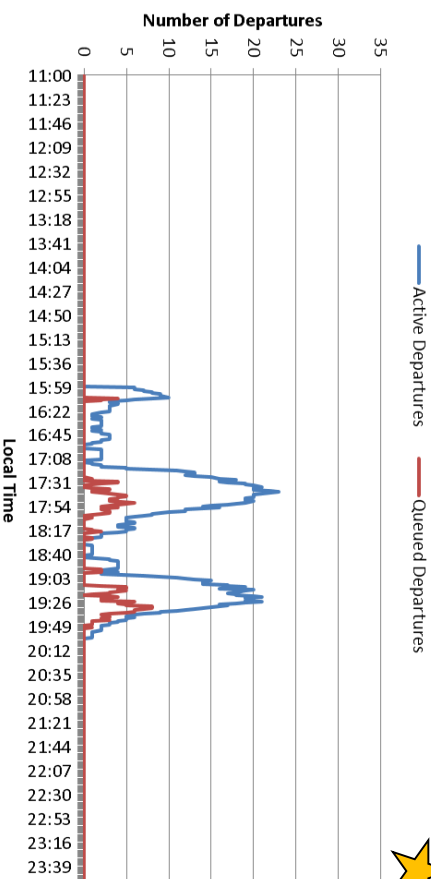
Departure Queue Length

TDQL = 5



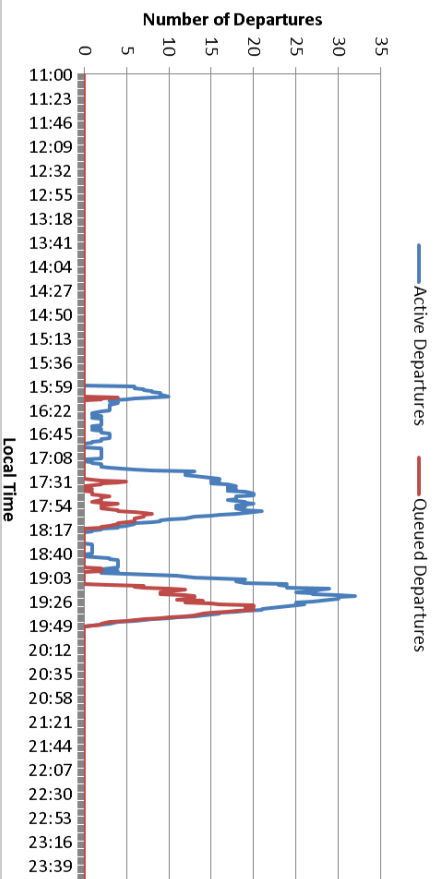
Departure Queue Length

TDQL = 3



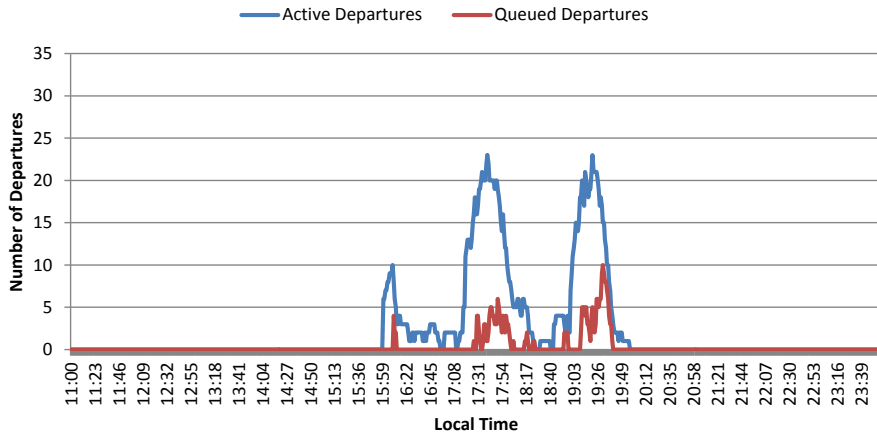
Departure Queue Length

TDQL = 8

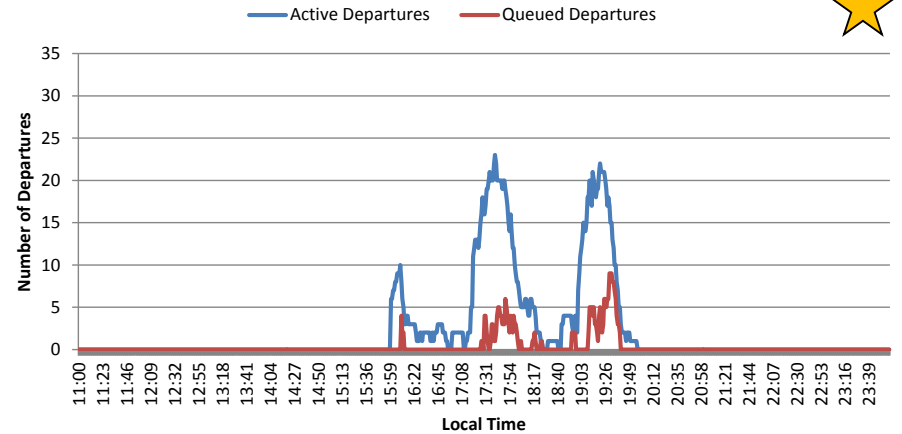


UC3: UDB SELECTION

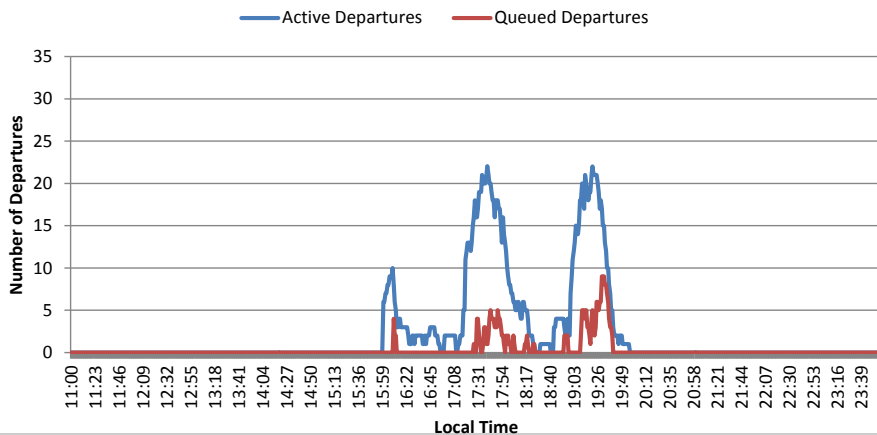
**Departue Queue Length
UDB = 1% of Capacity**



**Departue Queue Length
UDB = 3% of Capacity**



**Departue Queue Length
UDB = 5% of Capacity**



**Departue Queue Length
UDB = 8% of Capacity**

