Scheduling Improvements Following the Phase 1 Field Evaluation of the ATD-2 Integrated Arrival, Departure, and Surface Concept

William J. Coupe, Hanbong Lee, Yoon Jung, Liang Chen, and Isaac Robeson

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Background: Surface Management is a Challenging Task

= Departure  = Arrival
Background:
Airspace Technology Demonstration 2 (ATD-2)

*Integrated* Arrival, Departure, and Surface (IADS) traffic management
Phase 1 Field Evaluation at Charlotte Douglas International Airport (CLT) Sep 2017 – Sep 2018

Phase 1 Capabilities Include

- Data exchange and integration
- Departure scheduling for overhead stream insertion
- Tactical surface metering

Phase 1 field evaluation data helped identify scheduler improvements and guided the implementation of refinements enabling strategic Surface Metering Programs (SMPs)
Outline

• Overview of IADS Modeler and Scheduler
  • Arrival scheduling
  • Departure scheduling for Surface Metering Program (SMP)
  • Triggering metering ON
  • Compliance with scheduled times
• Summary
IADS Modeler: Trajectory Prediction

Runway utilization strategy provided by Air Traffic Controllers

TRACON controller runway intent

Time Based Flow Management (TBFM) deconflicted Scheduled Time of Arrival (STA)

Traffic Flow Management System (TFMS) Estimated Time of Arrival (ETA)

Traffic Management Initiatives (TMIs) and Controlled Takeoff Times (CTOTs)

Airline provided Earliest Off Block Time (EOBT) estimates

Tactical airline intent data from ramp controllers

Surface Trajectory Predictive Engine (runs every 10 seconds)

Departure Trajectory Logic:
- Earliest Off Block Time (EOBT)
- Unimpeded Off Block Time (UOBT)
- Unimpeded Movement Area entry Time (UMAT)
- Unimpeded Take Off Time (UTOT)
- Pushback duration model
- Ramp and AMA taxi time
- Trajectory Hovering Logic

Arrival Trajectory Logic:
- Predicted landing time
- Ramp and AMA taxi time
- IN time estimate for gate conflicts
- Gate conflict prediction
IADS Modeler: Scheduling Groups

- Flights assigned to scheduling groups using flight state and Earliest Off Block Time (EOBT) estimates provided by the airlines

- Scheduling groups used in logic to select next aircraft to schedule, e.g., all arrivals placed on timeline before departures
IADS Scheduler Logic

Step 1: Target TakeOff Time (TTOT)

TOBT = max[ UOBT , TTOT – UTT – TargetExcessQueueTime ]

UOBT = Unimpeded Off Block Time (from the airlines)
UTT = Unimpeded Transit Time (from the model)
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Predicted Landing Time Accuracy

IQR = InterQuartile Range (Q3 – Q1)

Actual - Predicted [Minutes]

Lookahead Prior to Actual ON

TBFM STA Median Error
TFMS ETA Median Error
TBFM STA Error IQR
TFMS ETA Error IQR
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Original Scheduler Design to Select Next Aircraft to Schedule

<table>
<thead>
<tr>
<th>Uncertain</th>
<th>Planning</th>
<th>Ready</th>
<th>Active</th>
<th>Arrival</th>
</tr>
</thead>
</table>

- Order of Consideration
  - Lower
  - Higher

- Departures placed on timeline after arrivals according to the Order of Consideration
- Original design inserted aircraft into the schedule in a hierarchical fashion where each group was scheduled before moving to next group
- This hierarchical structure creates instability when aircraft transition between groups
Target Take Off Time (TTOT) when Transitioning from Uncertain to Planning

TTOT Difference between Uncertain and Planning

- TTOT(Planning) - TTOT(Uncertain)
- Mean: -2.1, STD: 3.60

Frequency

Minutes
Target TakeOff Time (TTOT) Instability from Hierarchical Order of Consideration

UTOT = Unimpeded TakeOff Time (from modeler)
TTOT = Target TakeOff Time (from scheduler)

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When XYZ7 transitions from Planning to Active, the TTOT jumps down the timeline.

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= Active
= Planning
Target TakeOff Time (TTOT) Instability from Hierarchical Order of Consideration

$UTOT = \text{Unimpeded TakeOff Time (from modeler)}$
$TTOT = \text{Target TakeOff Time (from scheduler)}$

When $XYZ7$ transitions from Planning to Active, the TTOT jumps down the timeline.
Target TakeOff Time (TTOT) Instability from Hierarchical Order of Consideration

UTOT = Unimpeded TakeOff Time (from modeler)
TTOT = Target TakeOff Time (from scheduler)

a) UTOT TTOT

Planning departures scheduled after all Active departures placed on timeline

b)
Target TakeOff Time (TTOT) Instability from Hierarchical Order of Consideration

UTOT = Unimpeded TakeOff Time (from modeler)
TTOT = Target TakeOff Time (from scheduler)

a) UTOT | TTOT

- Planning departures scheduled after all Active departures placed on timeline
- XYZ7 transitions from Planning to Active the TTOT jumps down the timeline

b) UTOT | TTOT

- = Active
- = Planning
Target TakeOff Time (TTOT) Instability from Hierarchical Order of Consideration

UTOT = Unimpeded TakeOff Time (from modeler)
TTOT = Target TakeOff Time (from scheduler)

When XYZ7 transitions from Planning to Active the TTOT jumps down the timeline
First Scheduled First Served (FSFS) in Planning Group for Surface Metering Program

UOBT = Unimpeded Off Block Time (from modeler)
SOBT = Scheduled Off Block Time (from airline)

Sequence defined by First Come First Served (FCFS) principle:
UOBT + Transit Time
First Scheduled First Served (FSFS) in Planning Group for Surface Metering Program

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SOBT = Scheduled Off Block Time (from airline)

Sequence defined by First Come First Served (FCFS) principle: UOBT + Transit Time

Sequence defined by First Scheduled First Served (FSFS) principle: SOBT + Transit Time
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Sequence defined by First Come First Served (FCFS) principle:
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First Scheduled First Served (FSFS) in Planning Group for Surface Metering Program

TOBT = Target Off Block Time (from scheduler)

Controlled $U_{TOT}$

Sequence defined by Controlled $U_{TOT}$: TOBT + Transit Time

TTOT

FSFS when delay above Target

FCFS when delay below Target

Current Time
Delay above the Target excess queue time gives us the ability to gate hold and influence the sequence of aircraft that we deliver to the runway.
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Original Design: Trigger Metering ON Using Delay Predictions Based on EOBT

20171205: Excess Taxi Time and Gate Hold

- **Target**
- **Excess Taxi Time**
- **Gate Hold**

**Minutes**

**Takeoff Sequence in Bank**

Metering triggered ON early and aircraft were gate held when the delay was well below the Target excess queue time.
Revised Design: Trigger Metering ON Using Active Flights Delay and Delay Predictions

20180121: Excess Taxi Time and Gate Hold

- Target
- Excess Taxi Time
- Gate Hold

Metering triggered ON after delay naturally built up to the Target and additional delay was efficiently transferred from the taxiways to the gate.
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Target Off Block Time (TOBT) Compliance +/- 2 Minutes

TOBT Compliance

TOBT Compliance = 45.9%

Actual – Target [Minutes]
Compliance with the TMAT increased when aircraft were initially compliant with the TOBT
Optimal Target Movement Area entry Time (TMAT) Compliance +/- 5 Minutes

Optimal TMAT Compliance

- Actual Compliance = 65.9%
- Optimal Compliance = 83.6%
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- **Arrival scheduling**
  
  Predicted Landing Times for arrivals use TBFM STA when available else use TFMS ETA

- **Departure scheduling for Surface Metering Program (SMP)**
  
  Delay beyond the Target excess queue time gives us the ability to influence the sequence of aircraft

- **Triggering metering ON**
  
  Triggering metering ON performed best when accounting for active flights delay in addition to delay predictions

- **Compliance to scheduled times**
  
  TMAT compliance increased when aircraft were first compliant with the TOBT
Next Steps

• Evaluate the performance of strategic Surface Metering Programs (SMPs)

• Improve and evaluate performance of departure scheduling for overhead stream insertion including prescheduling with Earliest Off Block Time (EOBT)

• Incorporate constraints from the terminal boundary in a metroplex environment

• Tactical scheduling with Trajectory Option Sets (TOS)
Questions?

POC Jeremy Coupe: william.j.coupe@nasa.gov