

Fast-Time Simulation for Evaluating the Impact of Estimated Flight Ready Time Uncertainty on Surface Metering

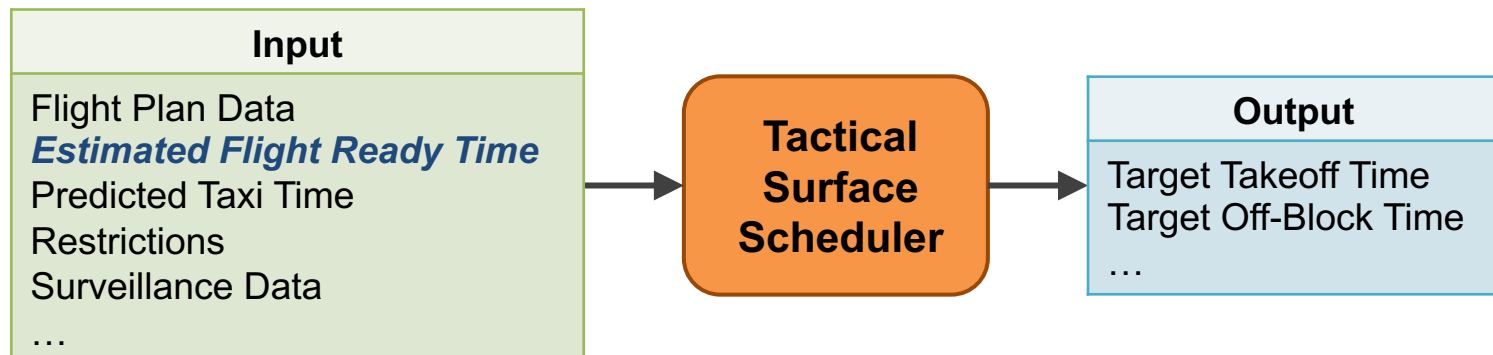
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- Motivation and Research Objective
- EOBT Model Development
- Fast-Time Simulation Platform
- EOBT Accuracy Impact Evaluation Using Fast-Time Simulation
- Summary

- Surface metering for efficient airport operations
 - Reduce excess taxi-out time by shifting wait time in departure queue to gates while engines are off
 - Enabled by a tactical surface scheduler
- Tactical surface scheduler
 - Calculate Target Takeoff Times (TTOT) of departures, considering unimpeded takeoff times and constraints
 - Provide pushback advisories to controllers



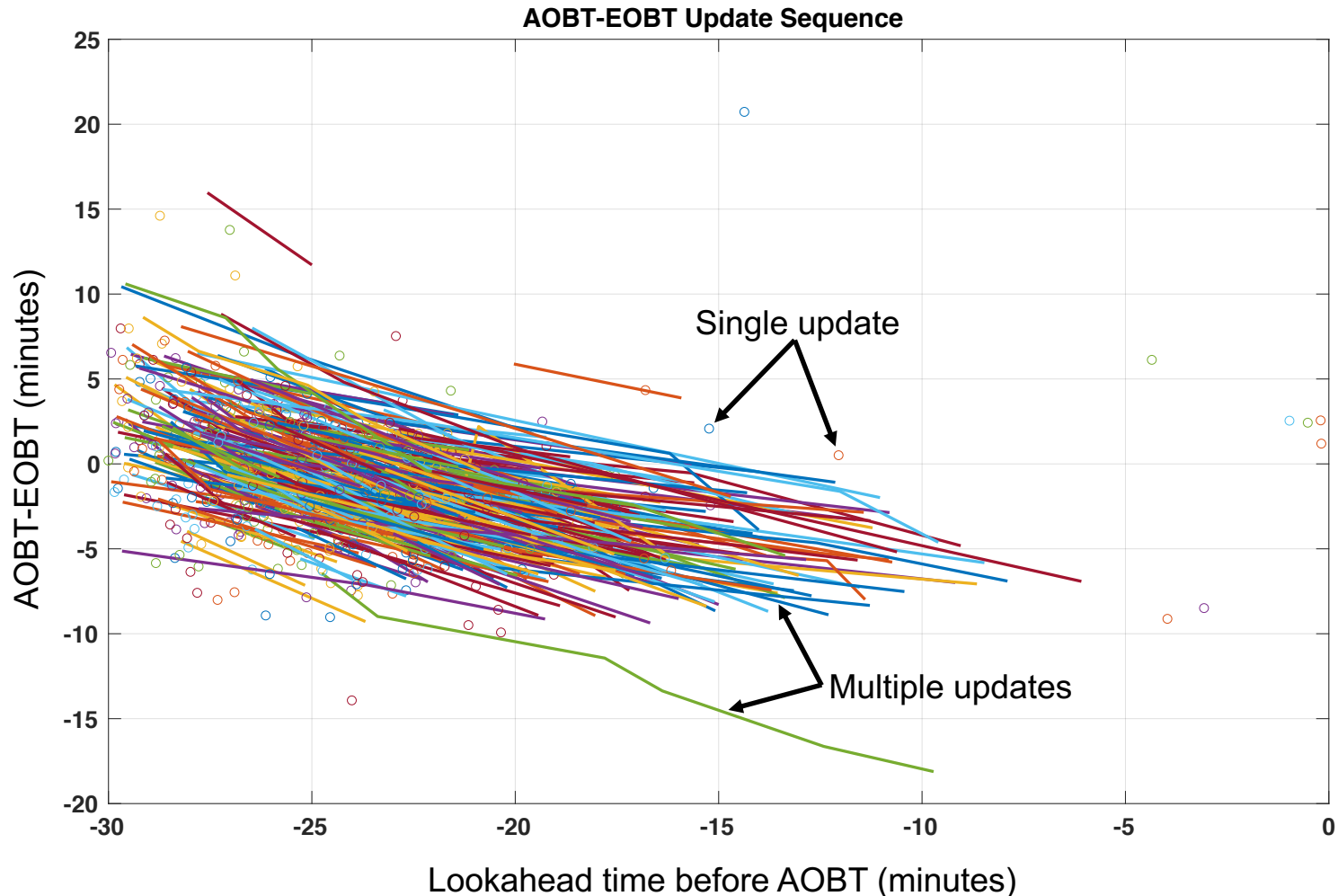
- Earliest Off-Block Time (EOBT)
 - Estimated flight ready time of departures
 - Provided by airlines based on flight readiness status
 - Used as input for a tactical surface scheduler
 - EOBT accuracy
 - One of key factors determining scheduler performance
 - Affected by uncertainties in actual flight operations
 - It is difficult to see direct impacts of the EOBT accuracy on scheduling in real operations
- Use ***fast-time simulation!***

- To develop an EOBT model representing actual EOBT data characteristics
- To integrate a fast-time simulation model with the EOBT model and ATD-2 tactical surface scheduler
- To evaluate the impact of EOBT accuracy on airport performance and benefits of surface metering

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- Data source
 - EOBT data from one-week flight data at Charlotte Douglas International Airport (CLT) in February 12-18, 2018
 - Sample size after data filtering
 - Total flights: 2,280
 - EOBT updates: 3,761
- Variables
 - EOBT update times
 - Number of EOBT updates
 - EOBT accuracy = AOBT – EOBT
 - AOBT: Actual Off-Block Time (actual pushback time)
 - EOBT: Earliest Off-Block Time (estimated flight ready time)

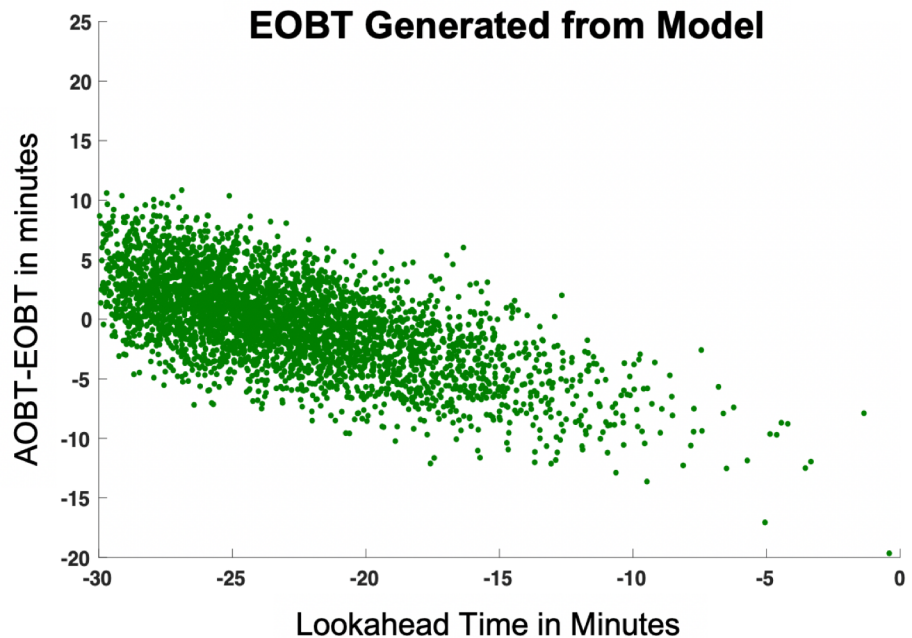
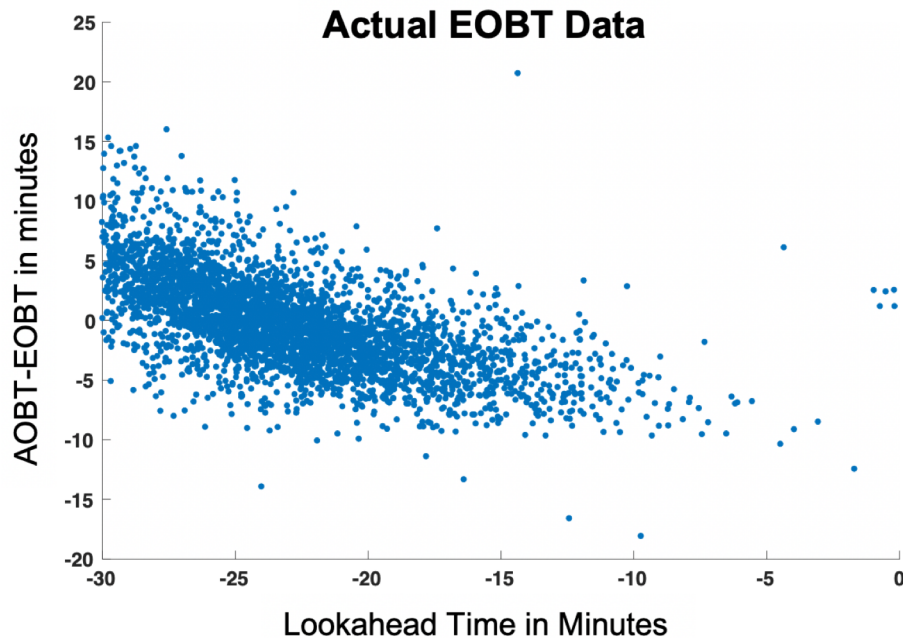
- Key elements: EOBT update time, update frequency, and accuracy
- EOBT becomes conservative as it approaches AOBT



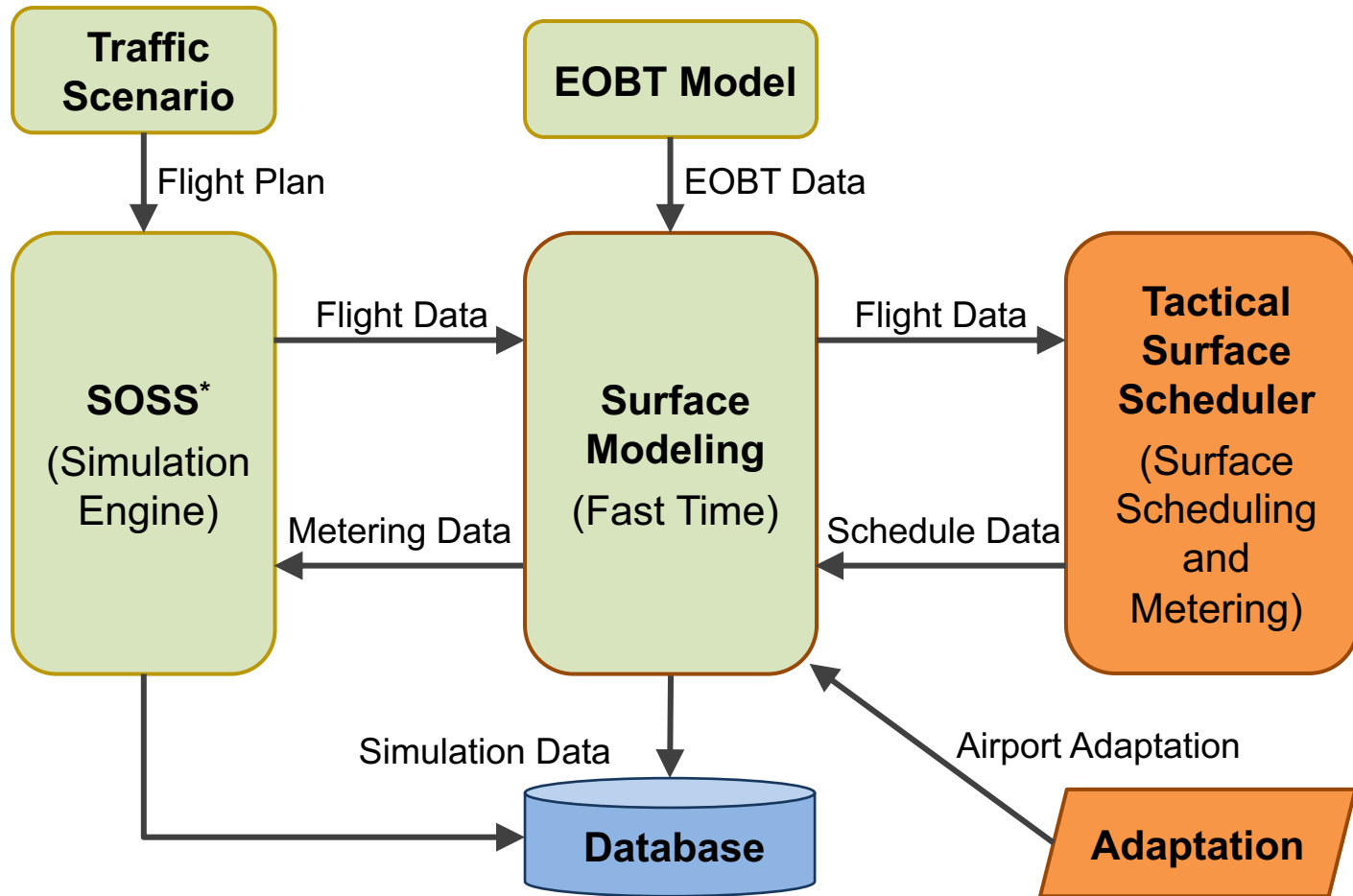
- Two-step approach
 1. Model EOBT update times
 - Define the number of EOBT updates per flight
 - Determine the lookahead time when EOBT is updated
 2. Model EOBT accuracy at the update times
 - Assume a normal distribution with zero mean at each time bin within 30 minutes before AOBT
 - Estimate a sigma value for all lookahead times
- Linear regression model for EOBT accuracy
$$Y = c_0 + c_1 * X_k + \text{Normal}(0, \sigma)$$
 - Y : EOBT accuracy
 - X_k : EOBT update time, $k = 1, 2, \dots, n$
 - n : number of EOBT updates

Linear regression model: $Y = c_0 + c_1 * X_k + Normal(0, \sigma)$

- EOBT update frequency: 1.65 per flight in 30 minutes
- Sigma value for EOBT accuracy model: 3.02 minutes
- Coefficients fitted to actual data: $c_0 = -12.67$, $c_1 = -0.54$



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* SOSS: Surface Operations Simulator and Scheduler

- Four days with heavy traffic at CLT (9-11am)
- South flow configuration
 - Departures: 18C, 18L
 - Arrivals: 18R, 18C, 18L

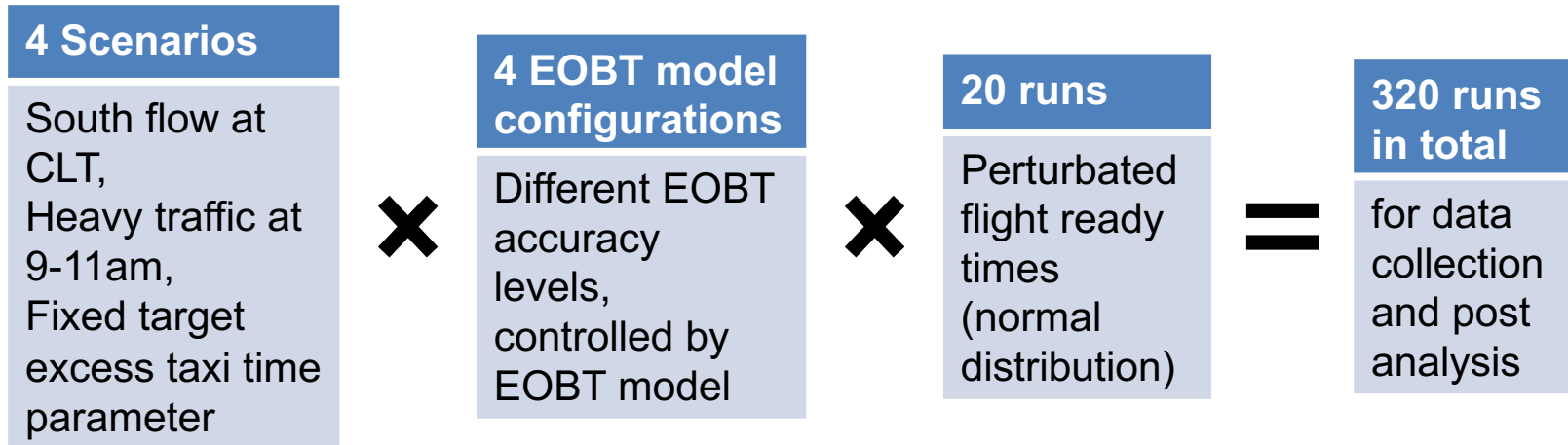
Date	Dep #	Arr #
1/22/2018	92	95
1/23/2018	91	84
2/12/2018	98	95
2/14/2018	91	78



- Assumptions for validation
 - Departure Flight Ready Time = Actual Off-Block Time
 - Surface metering: OFF
- Operational parameters for tuning
 - Adjusted taxi speeds and pushback times
 - Adjusted runway separation times
- Validation
 - Compared simulation output with actual operations data in terms of various performance metrics
 - Showed a good match with each other

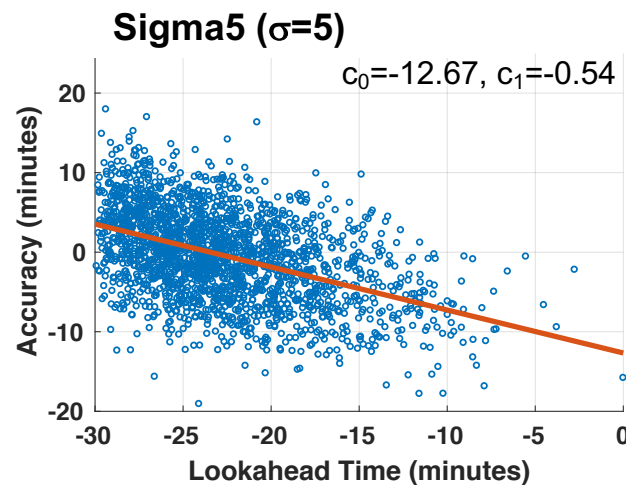
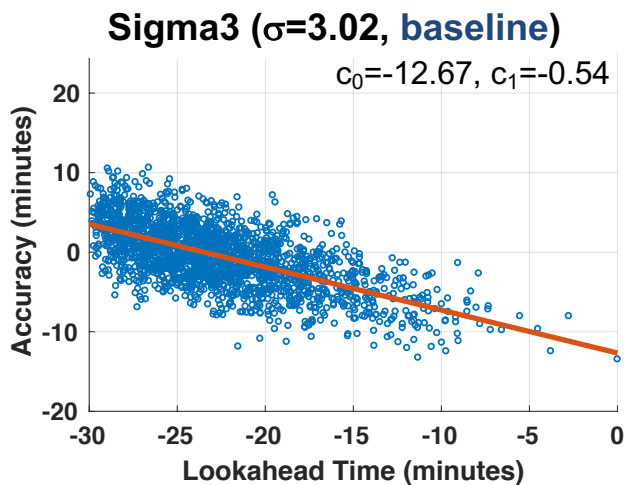
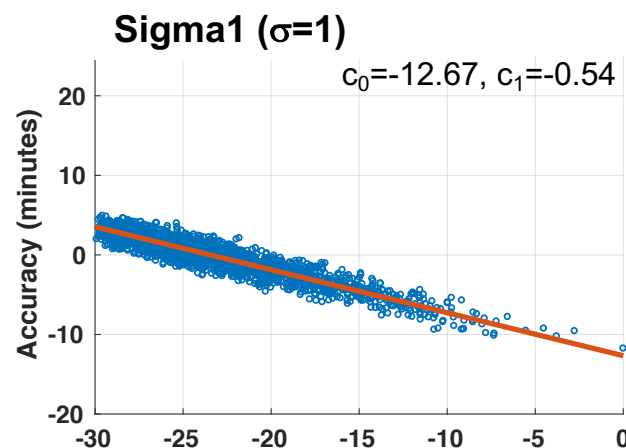
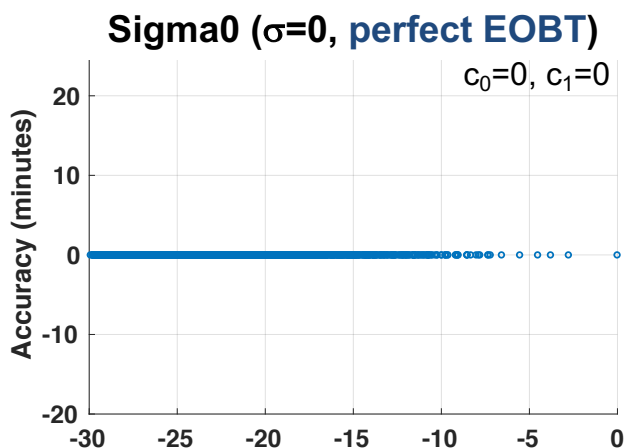
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- Simulation setup

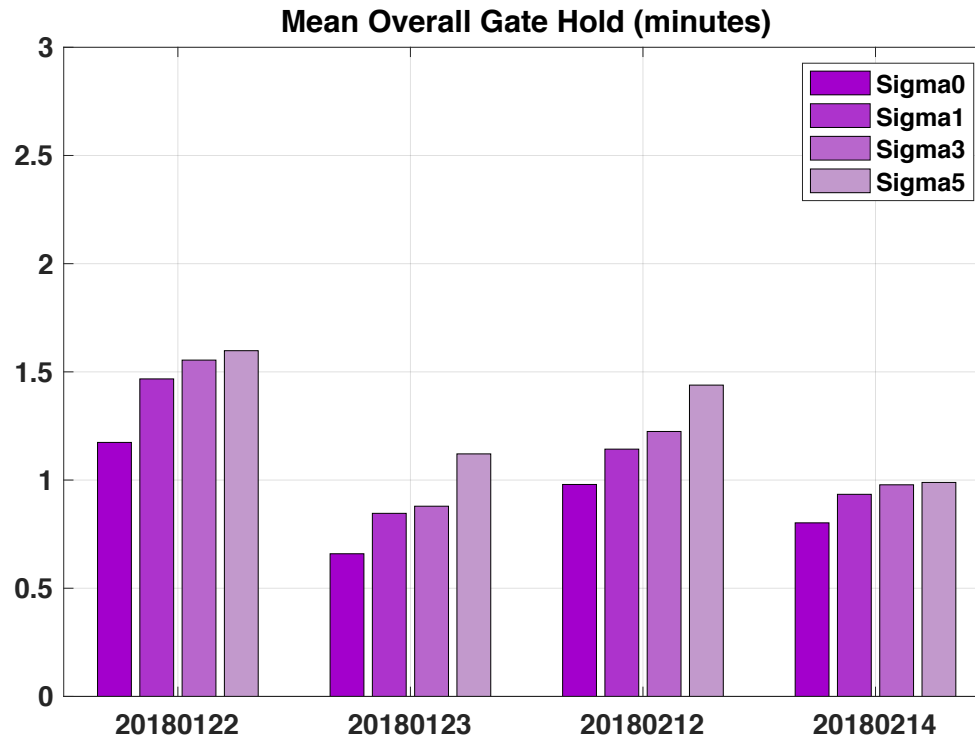


- Performance metrics
 - Gate hold
 - Taxi-out times
 - Takeoff delay
 - Target takeoff time predictability

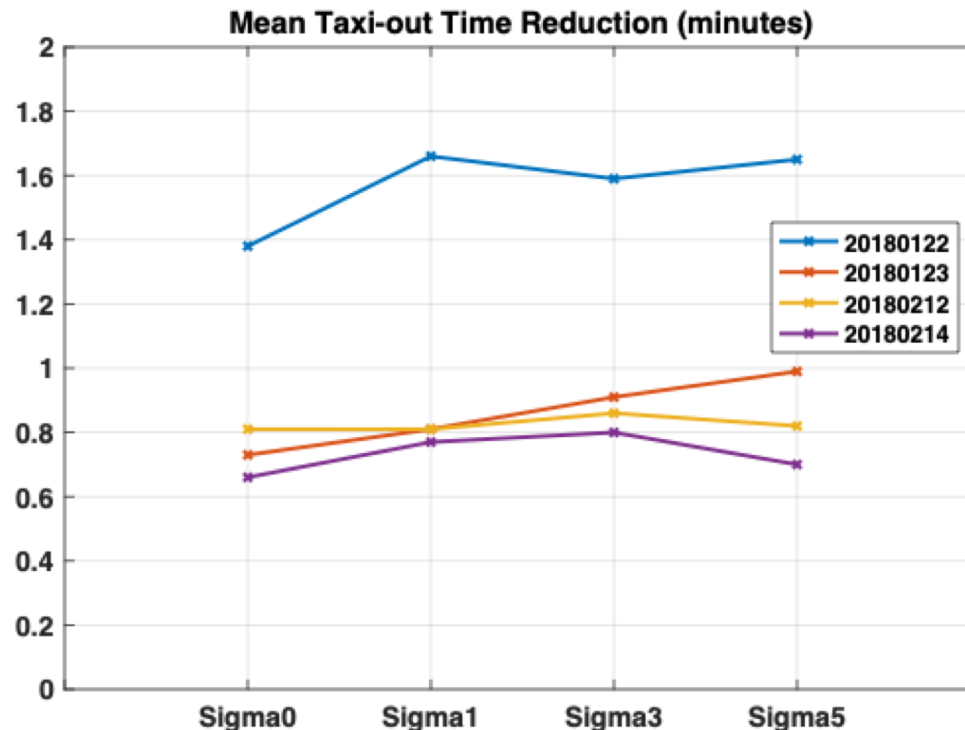
Test 4 cases with different EOBT accuracy levels



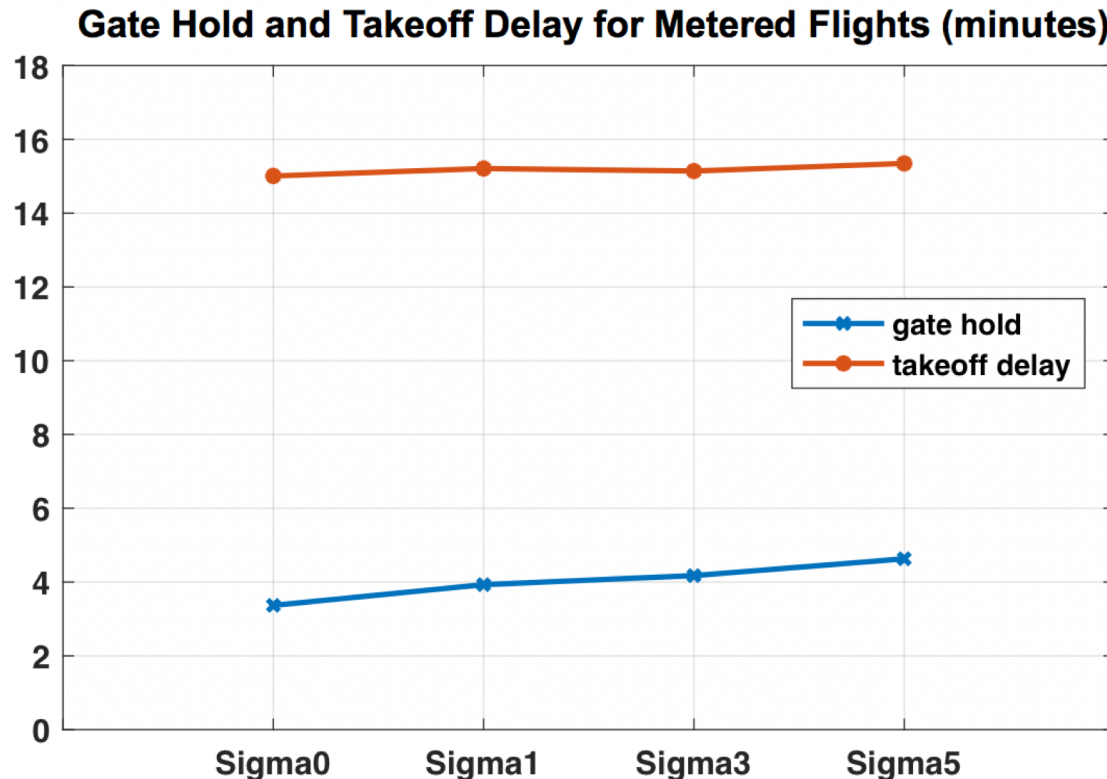
- Numbers of metered flights are almost constant, with the fixed target excess taxi time parameter
- Gate hold = Target Off-Block Time – Flight Ready Time
 - Gate hold in Sigma0 is due to heavy traffic demand
 - Additional gate hold is induced by EOBT uncertainty



- Mean taxi-out time reduction by gate holding, compared to no surface metering
- Surface metering reduces taxi-out times
- Additional gate hold induced by EOBT uncertainty can sometimes help reduce taxi time

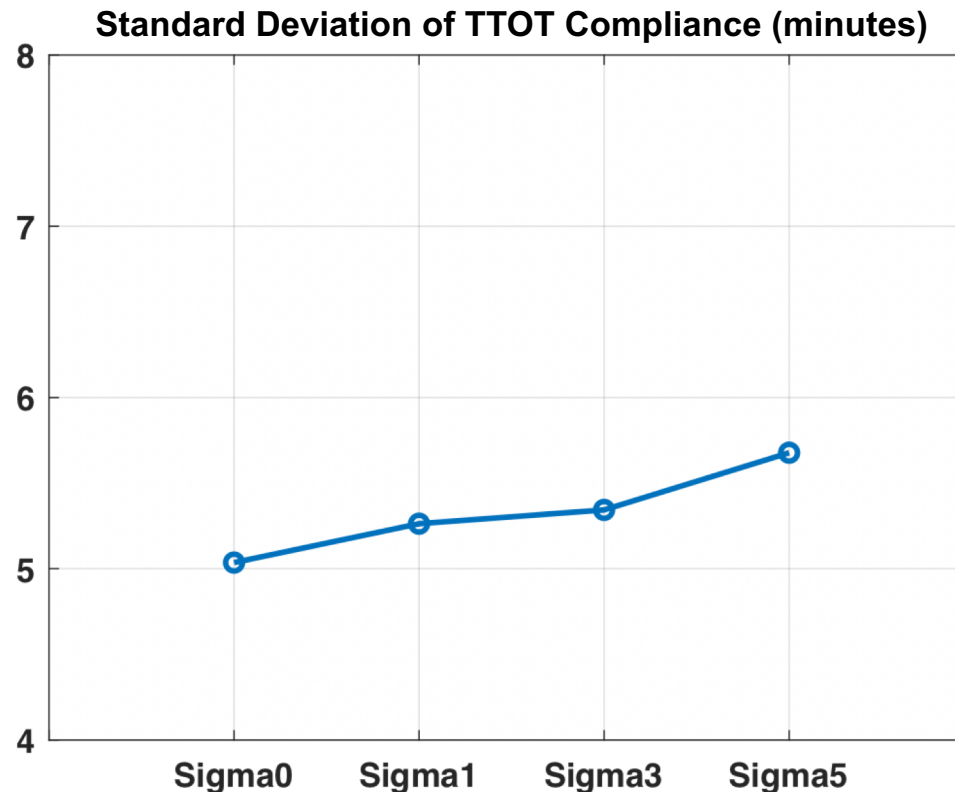


- Takeoff delay is not affected by EOBT accuracy, but dominated by traffic demand
- No significant correlation between gate hold and takeoff delay due to taxi time reduction





- Measured by the standard deviation of TTOT compliance (= difference between actual and target takeoff times)
- Better EOBT quality can help better TTOT predictability, making scheduler predict takeoff times more accurately



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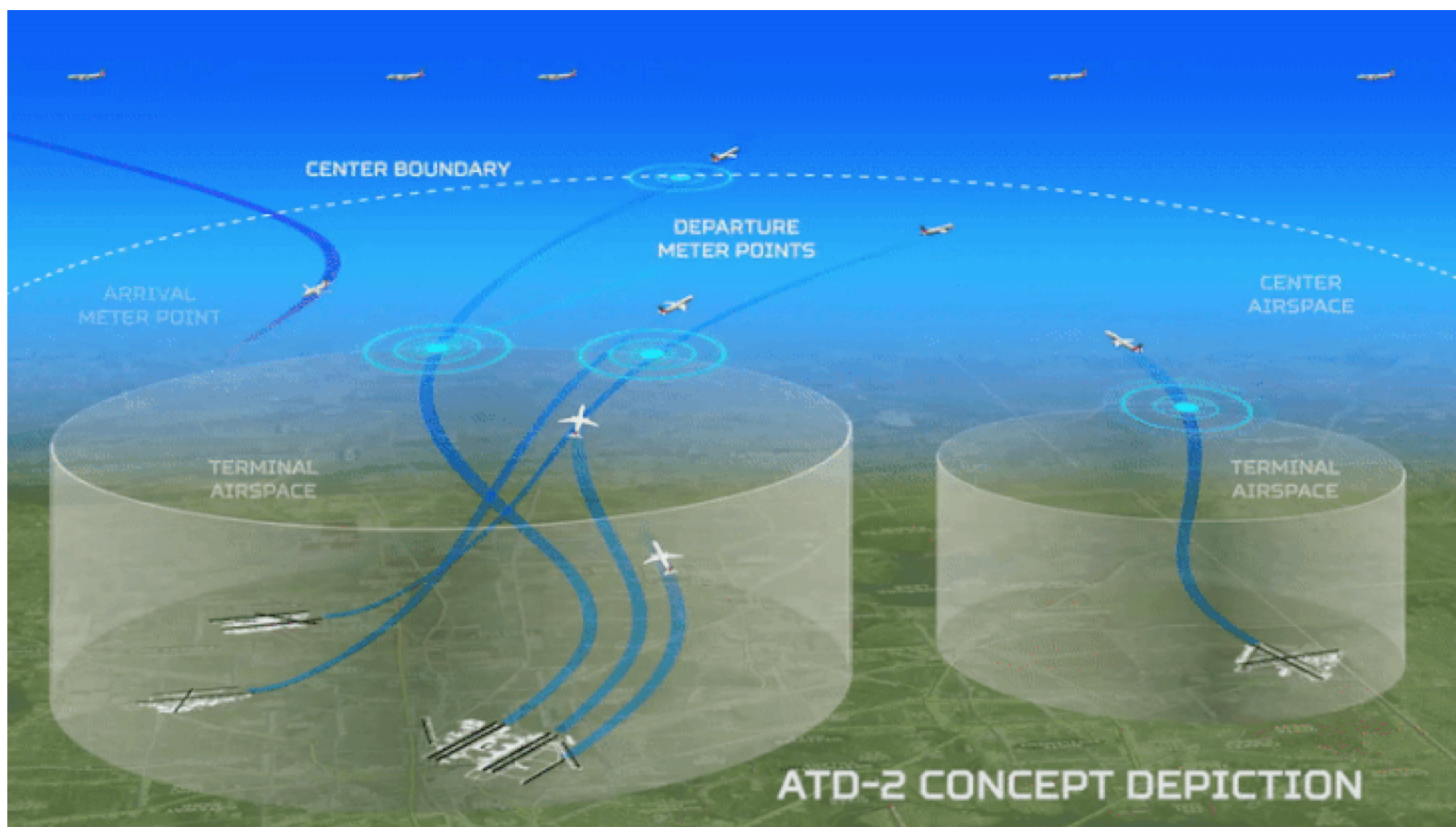
- Developed a linear regression EOBT model
- Integrated the EOBT model with fast-time simulation engine and a tactical surface scheduler
- Evaluated the impacts of EOBT accuracy on surface metering performance through fast-time simulations
- Simulation results showed that EOBT uncertainty might
 - Increase gate hold times,
 - Help reduce taxi-out time sometimes,
 - Make no impact on takeoff delay, and
 - Lower scheduler's takeoff time predictability

Thank You!

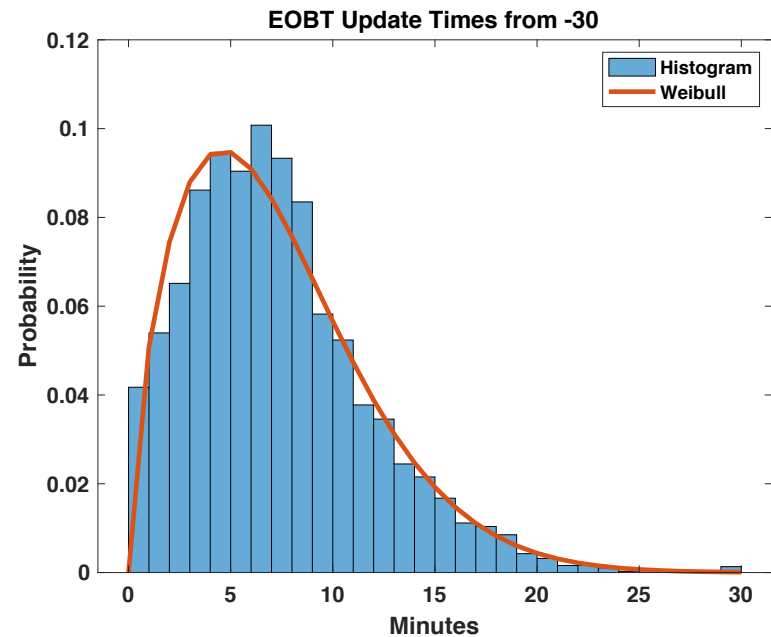
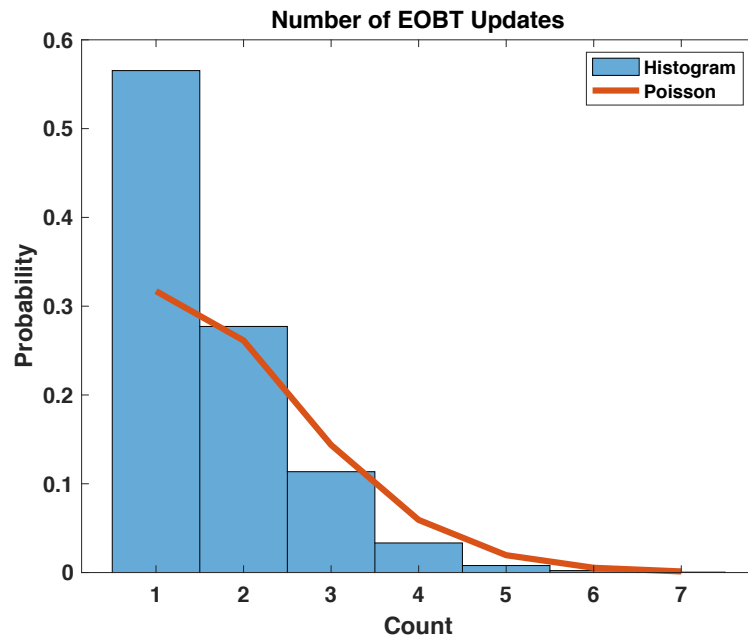
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Backup

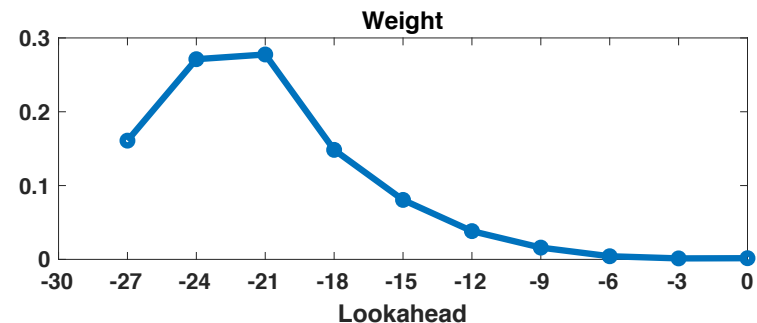
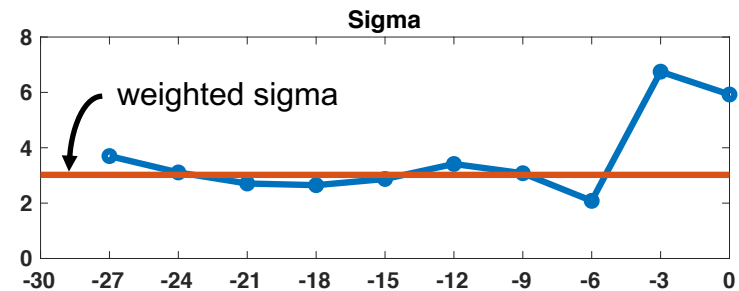
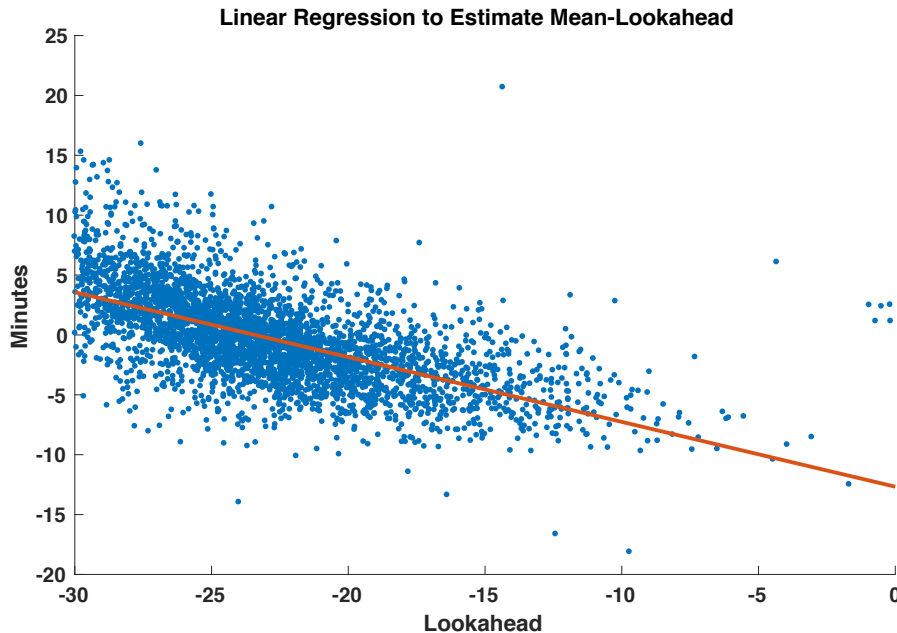
- To develop the Integrated Arrival, Departure, and Surface (IADS) traffic management capabilities



- Fit a probability distribution, $PD1$, as the number of EOBT updates (per flight) \rightarrow Poisson distribution
- Fit another probability distribution, $PD2$, as the time elapsed from the reference time (-30min before AOBT) to the EOBT update time \rightarrow Weibull distribution
- For each flight, sample the two distributions to obtain
 - Update time $X_k = -30 + \text{random}(PD2)$, $k = 1, 2, \dots, \text{random}(PD1)$



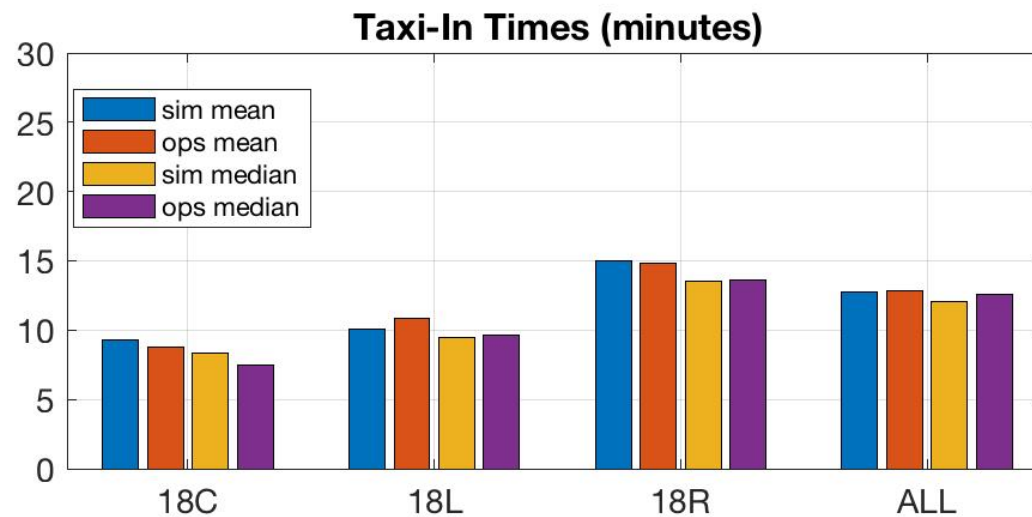
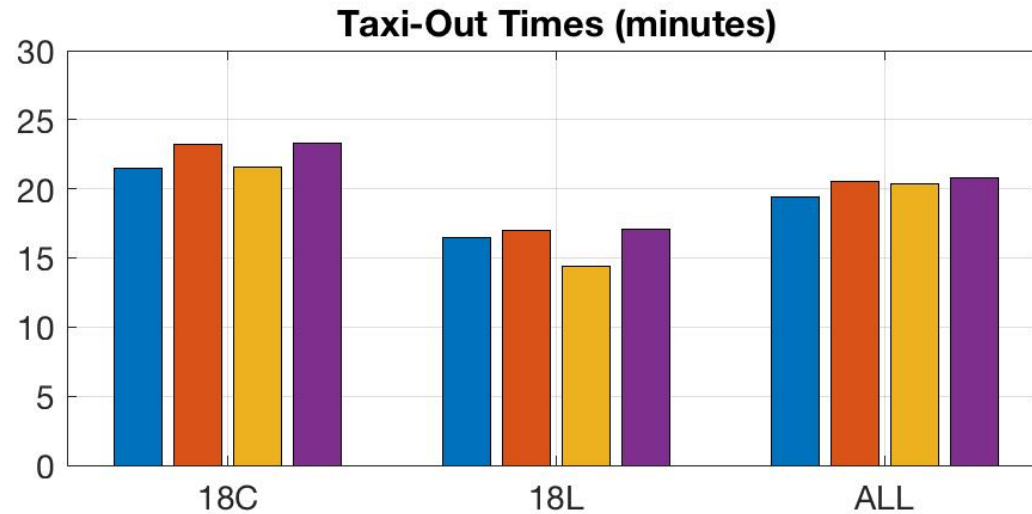
- Fit a sequence of probability distributions in 3-min bins within [-30, 0]
- Calculate the mean weighted by the data sample size in each time bin to obtain an overall weighted sigma (red line)
- Make a probability distribution, *PD3*, with zero mean and weighted sigma value
- Linear regression model for EOBT accuracy along lookahead time
 - EOBT accuracy $Y = c_0 + c_1 * X_k + random(PD3)$, X_k : EOBT update time



Simulation Model Validation: Taxi-Out/In Time Comparison



- Example scenario: 20180122

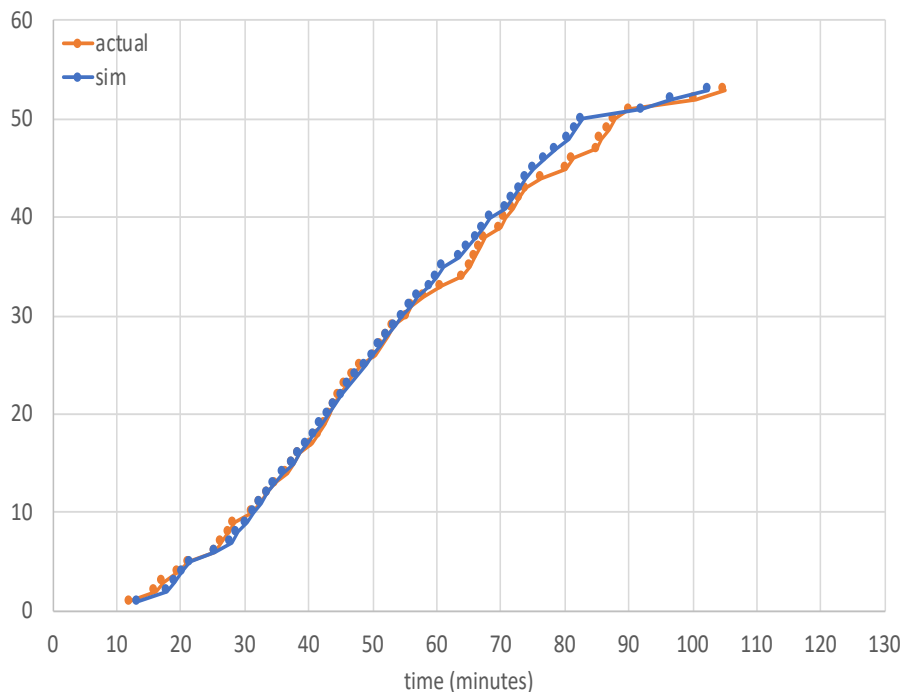


Simulation Model Validation: Departure Runway Throughput Comparison

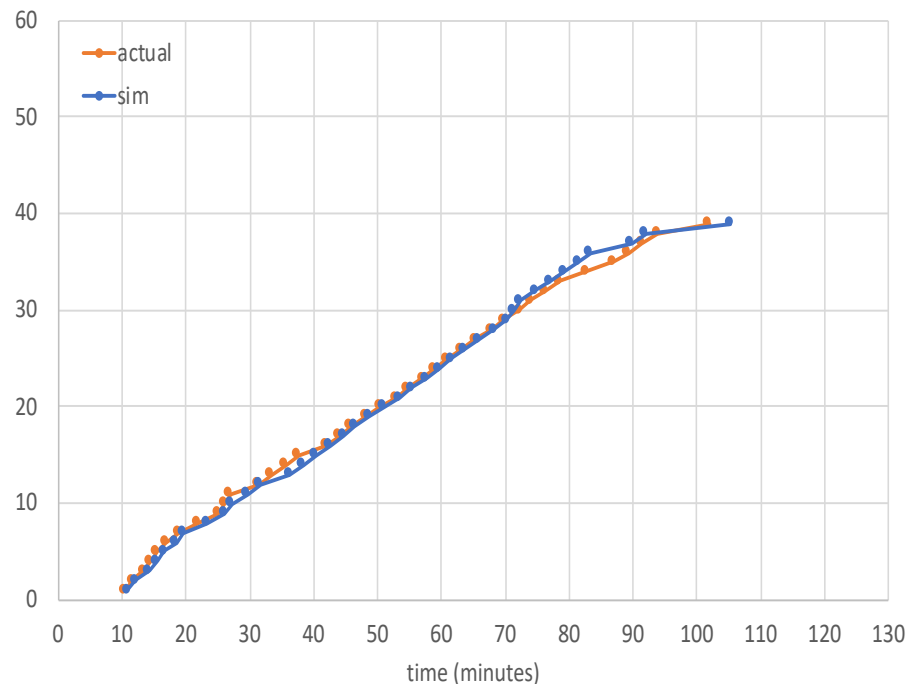


- Example scenario: 20180122

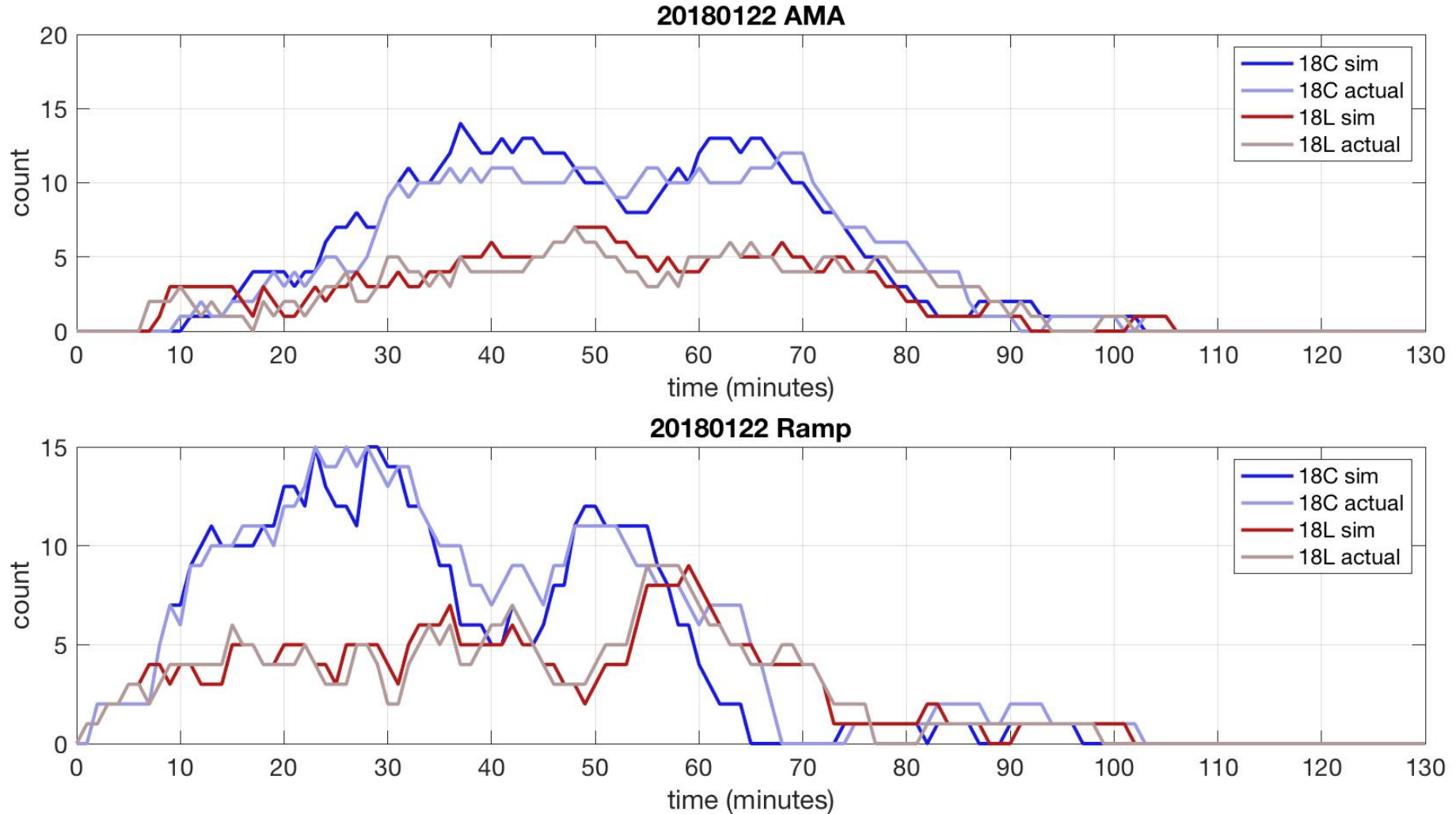
18C Accumulated Runway Throughput



18L Accumulated Runway Throughput

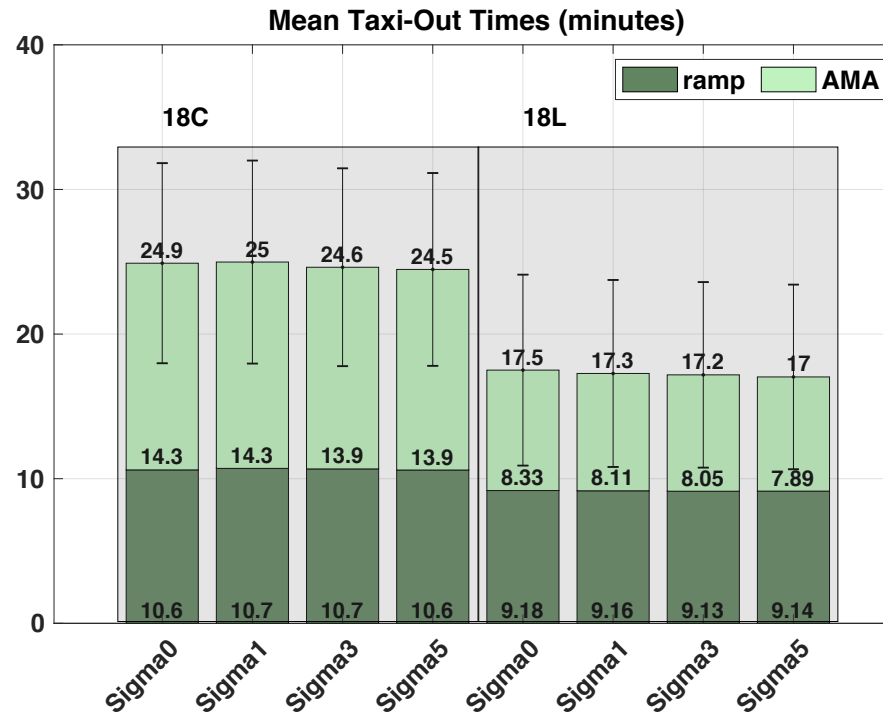


Simulation Model Validation: Departure Surface Count Comparison



- Average taxi-out times look constant, regardless of EOBT accuracy
- Departure queue size and AMA taxi time are maintained by the given target excess taxi time parameter

Example
Scenario:
20180122



- Target takeoff time (TTOT) compliance
 - Actual Takeoff Time – Target Takeoff Time
 - Not affected by EOBT accuracy
- TTOT predictability
 - Measured by the standard deviation of TTOT compliance
 - Better EOBT quality can help better TTOT predictability

