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# Runway Performance Database and Surface Performance Evaluation


N. Hinze, N. Mirmohammadsadeghi, M. Rimjha, M. Bollempalli, A. Izadi
Principal Investigators: S. Hotle and A.A. Trani
Virginia Tech


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# Outline of the Presentation and Acknowledgements

- Objectives and need for aircraft ground behavior data
- Landing events database
- Taxi event extraction tool
- Conclusions

FAA projects funded through the National Center of Excellence for Aviation Operations Research (NEXTOR II)

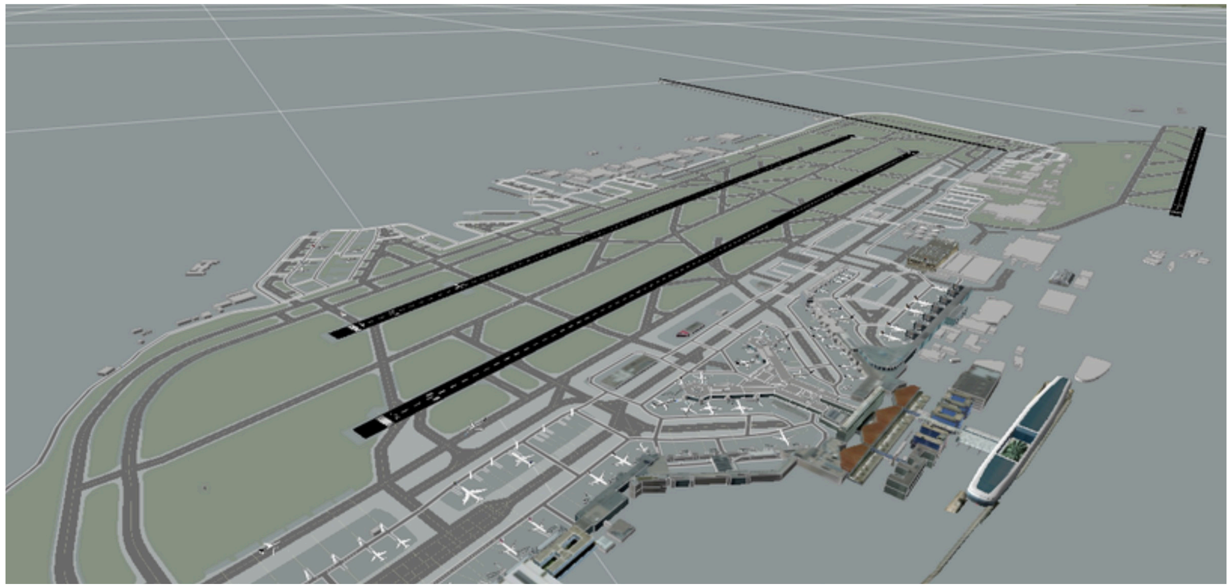
**FAA Project Sponsors:**
***Kent Duffy and Lauren Vitagliano***
Landing Events Database and Runway Exit Design Model

**John Gulding**
Aircraft Taxi Event Extraction from ASDE-X Surveillance for Surface Performance Evaluation

# The Need for Surface Aircraft Data and Models

- Runway and taxiway aircraft behavior data is important in the design (or re-design) of airport infrastructure
- Most fast-time airport/airspace simulation tools include detailed airport network information
- The same tools, do not provide unified guidance about individual aircraft behavior characteristics on the ground
- The purpose of the **tools presented** is to help airport planners and designers understand individual aircraft behavior on the ground

Source: Jeppesen
Total Airspace and Airport Modeler (TAAM)



Source: Airtopsoft, AirTOp

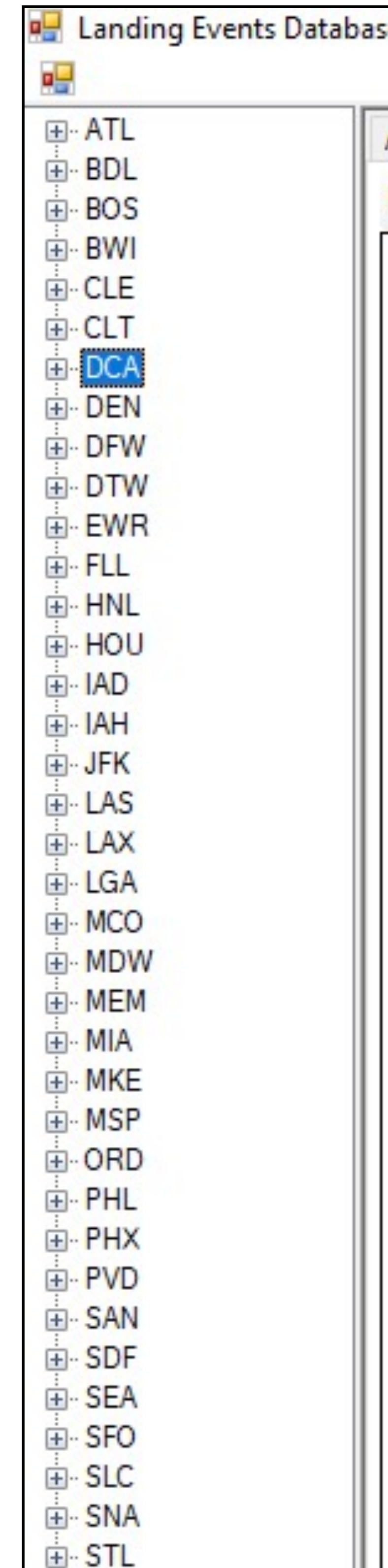
# Information Required in Airport Design and Fast-Time Simulation Tools

- Landing roll performance
  - Landing runway occupancy times
  - Runway exit use information
  - Runway deceleration characteristics
  - Runway exit speeds
- Takeoff roll performance
  - Departure runway occupancy times
  - Takeoff acceleration characteristics
- Taxi-in and taxi-out travel times
- Unimpeded taxi-in and taxi-out times


# Landing Events Database

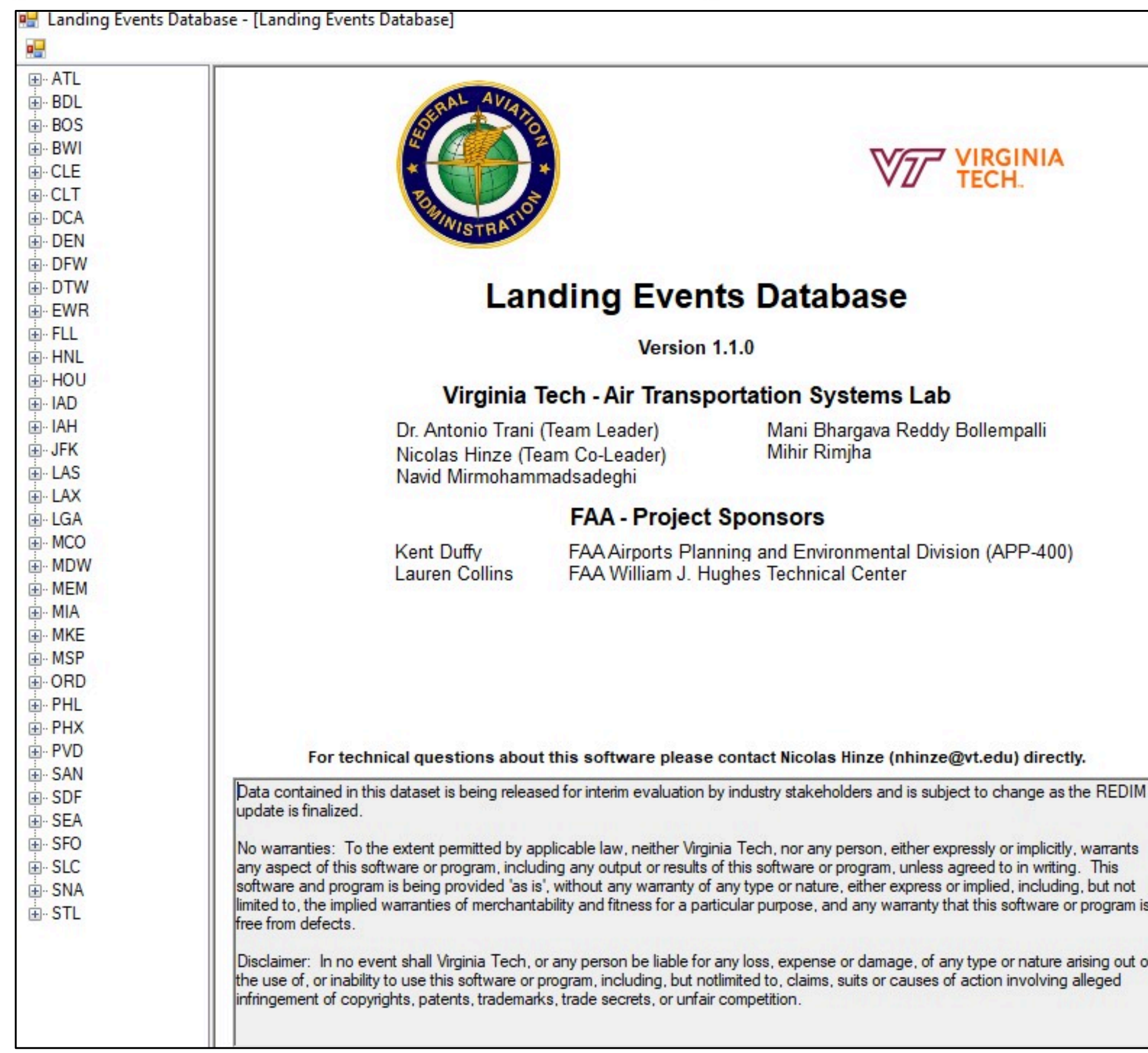
# FAA/Virginia Tech Landing Events Database Version 1.1

- A large database with detailed landing events extracted from ASDE-X adaptation data
- Contains data for all 37 U.S. airports (years 2015 and 2016)
  - 11.8 million landing event records
  - 800 million track points from runway threshold to hold bar
  - 150 GB size (Virginia Tech/Amazon Web Server)
  - Includes 3,840 runway exits
- ASDE-X data provided by FAA Technical Center (Tom Tessitore)
- Model validation using video taken at three U.S. airports
  - Chicago O’Hare (ORD)
  - Charlotte-Douglas International (CLT)
  - Washington Reagan National airport (DCA)

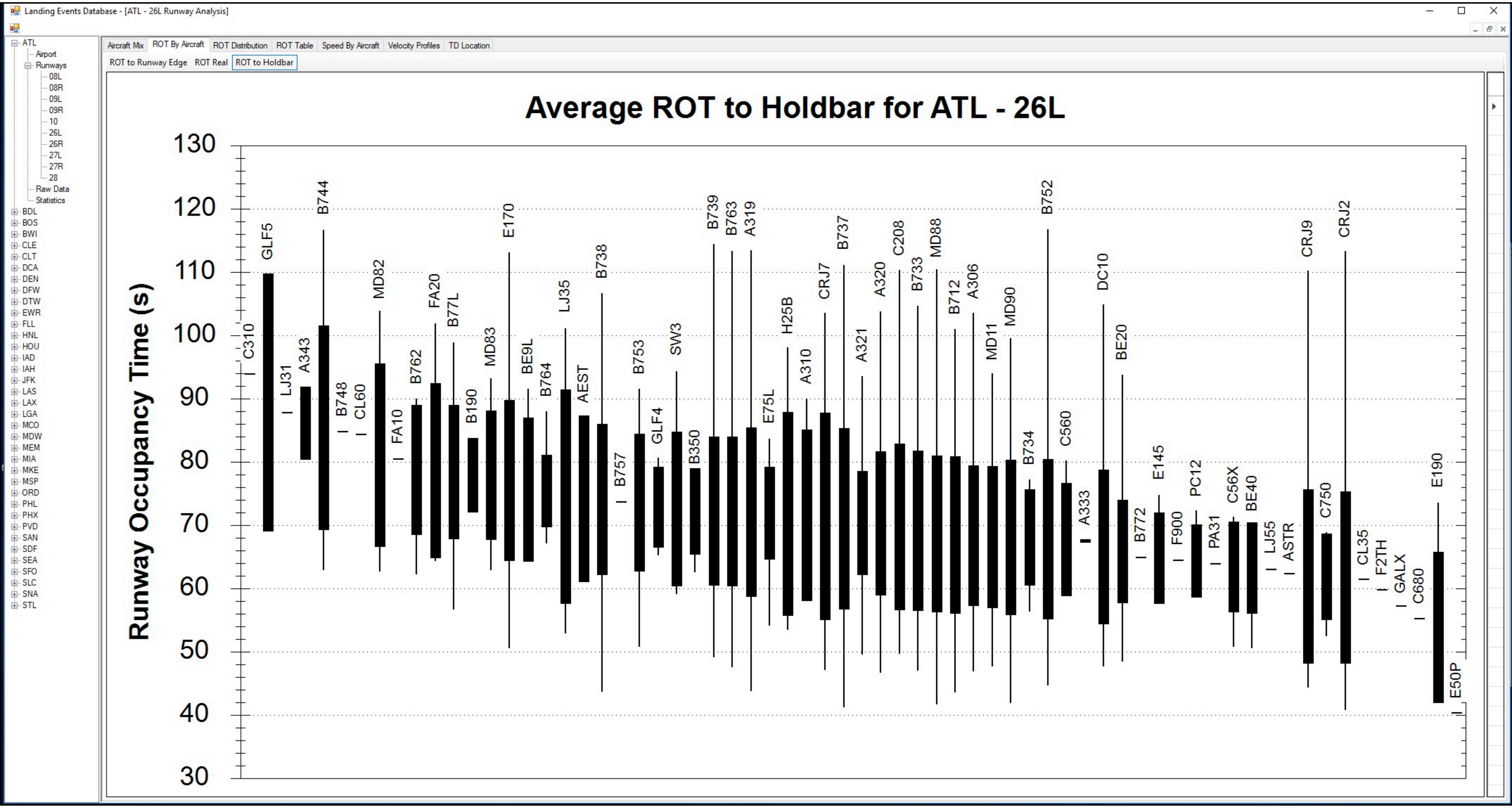
# FAA/Virginia Tech Landing Events Database


Windows 7/10 Application

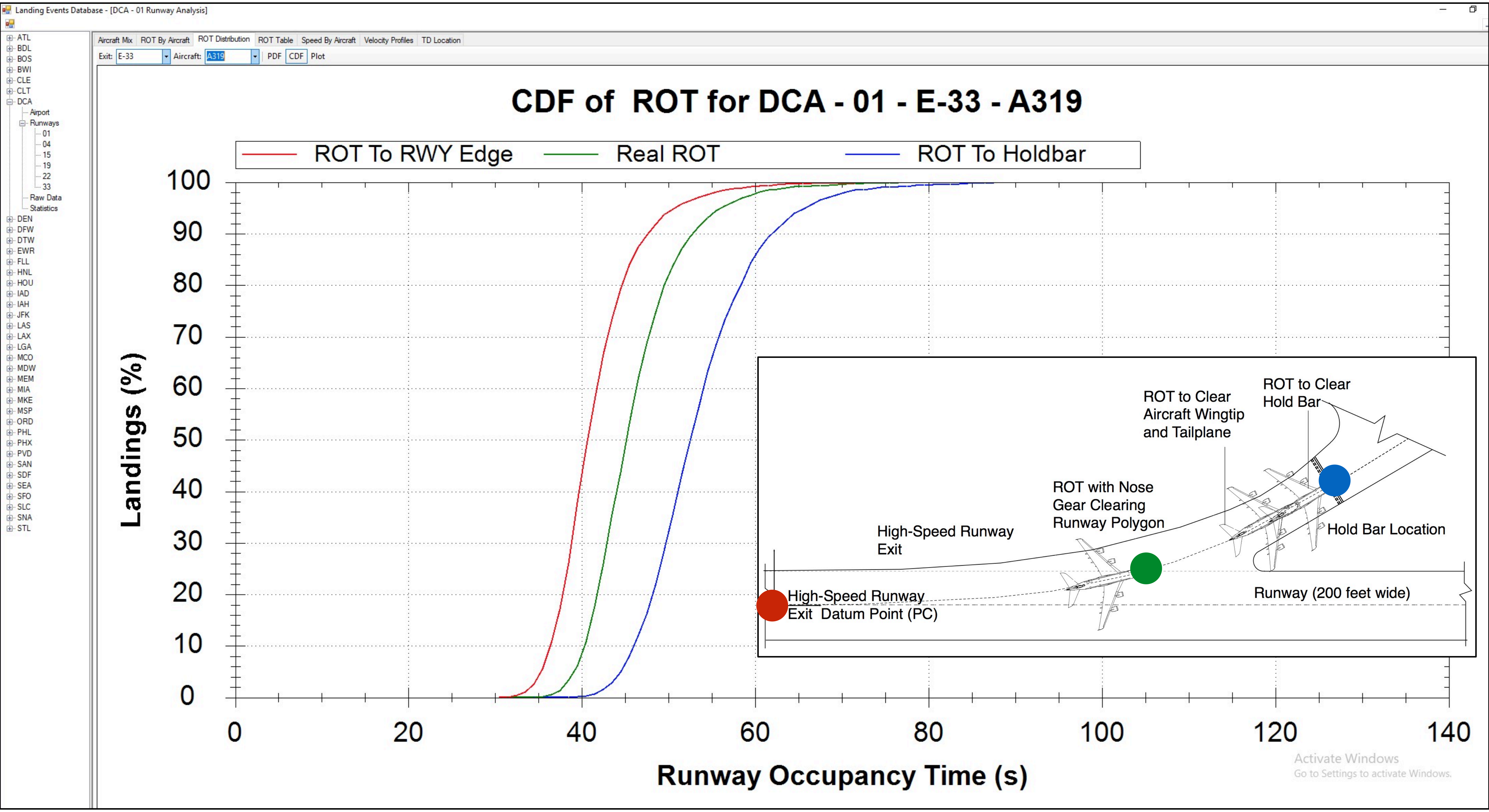




- Database uses Airport Surface Detection Equipment (ASDE-X) data
- Algorithms developed to predict landing roll parameters (used in new Runway Exit Design Model)

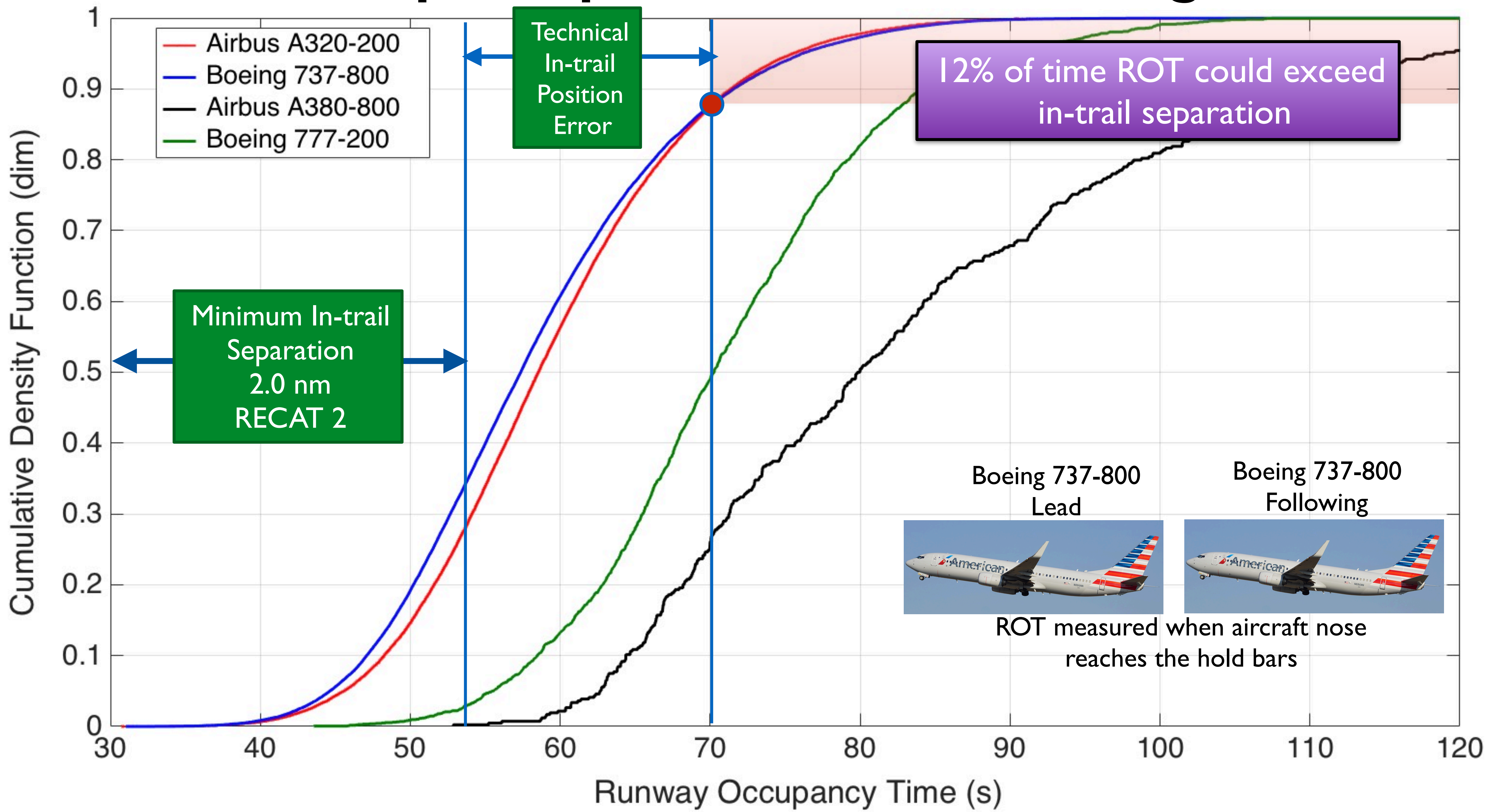
# Database Contains Information on Runway Occupancy Times for Individual Aircraft



# Cumulative Density Function of Runway Occupancy Times by Aircraft/Airport

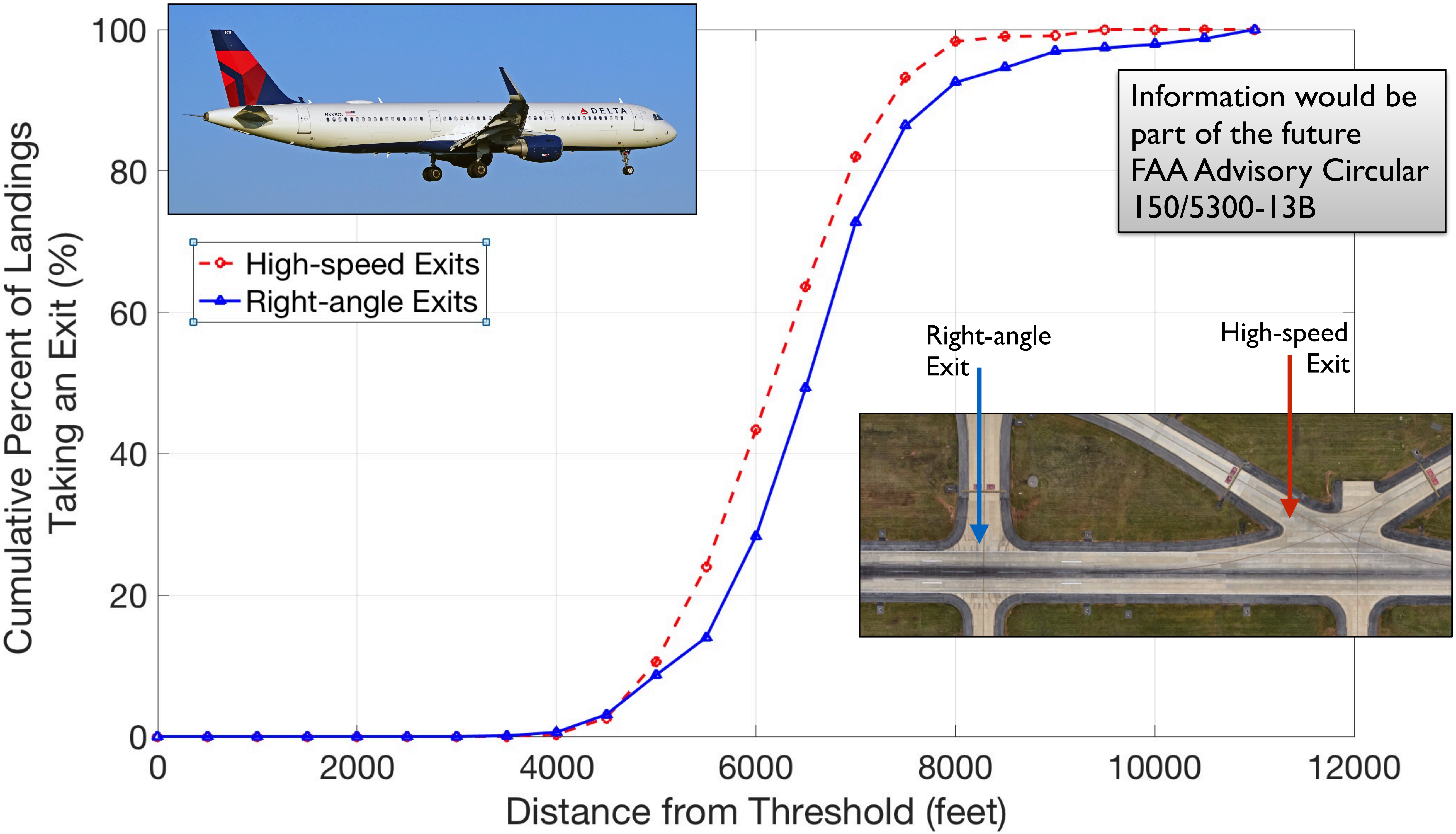


# Importance of Runway Occupancy Time in Future Airport Operations (Wake Re-categorization)




source of data: ASDE-X (37,383 Boeing 737-800 operations at 20 US airports)

# Operational Landing Roll Distance Distribution
# Airbus A321 Data



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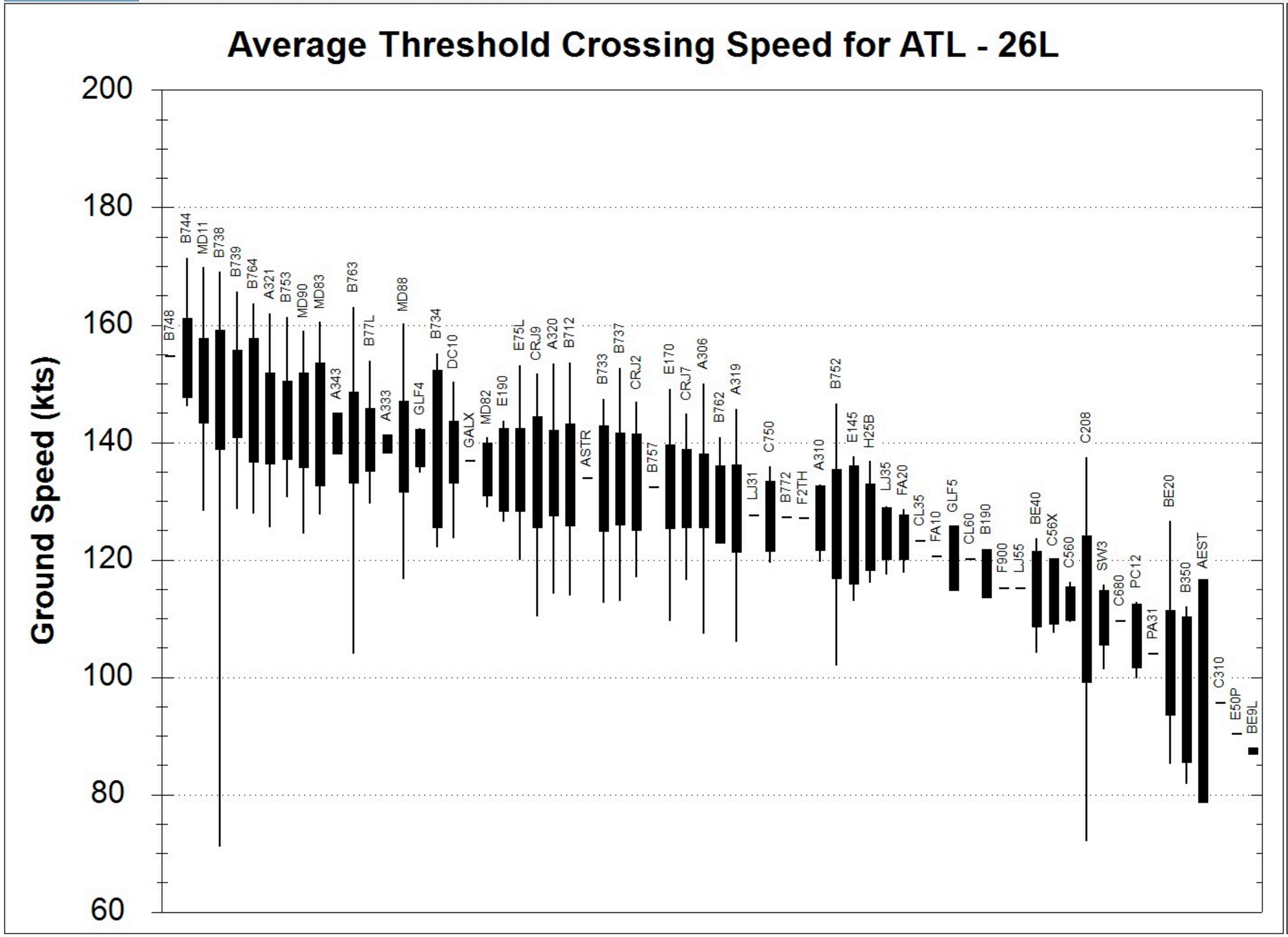
# Average Runway Threshold Ground Speeds

Landing Events Database - [ATL - 26L Runway Analysis]

ATL: Airport, Runways (08L, 08R, 09L, 09R, 10, 26L, 26R, 27L, 27R, 28), Raw Data, Statistics
BDL, BOS, BWI, CLE, CLT, DCA, DEN, DFW, DTW, EWR, FLL, HNL, HOU, IAD, IAH, JFK, LAS, LAX, LGA, MCO, MDW, MEM, MIA, MKE, MSP, ORD, PHL, PHX, PVD, SAN, SDF, SEA, SFO, SLC, SNA, STL

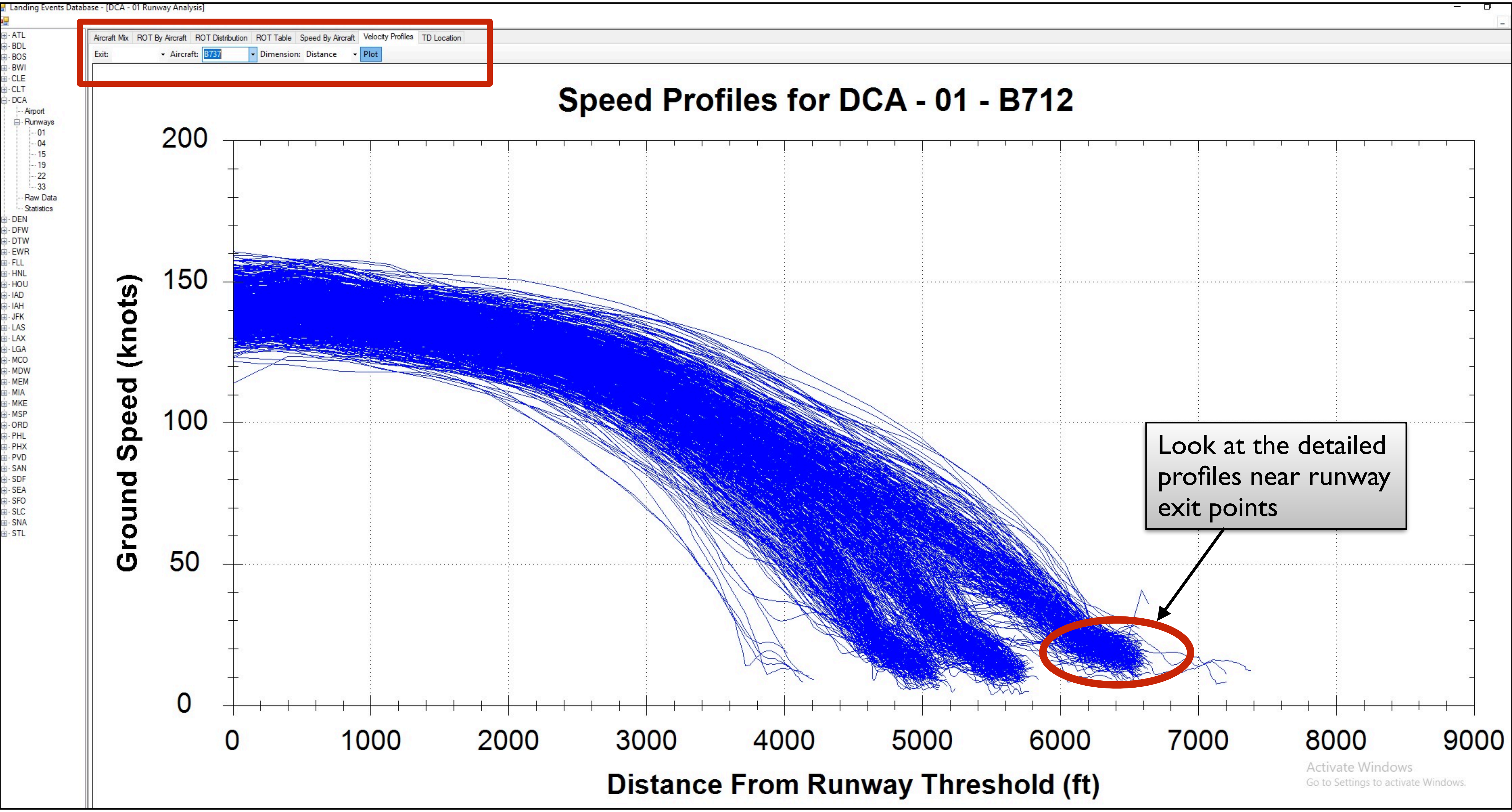
Aircraft Mix | ROT By Aircraft | ROT Distribution | ROT Table | Speed By Aircraft | Velocity Profiles | TD Location

Threshold Crossing Speed | Touchdown Speed | Exit Speed at PC | Exit Speed at RWY Edge | Exit Speed at Holdbar

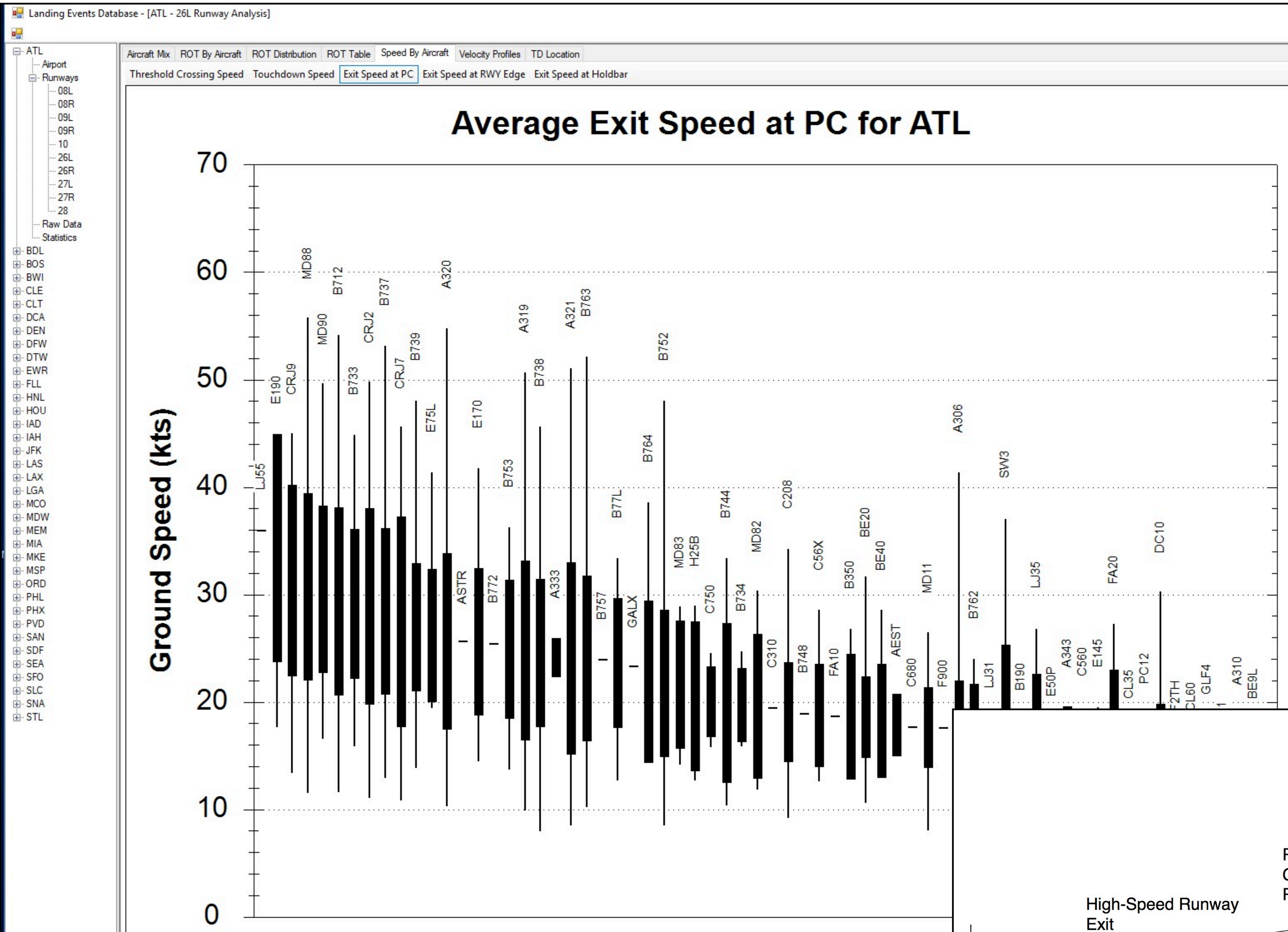



| Aircraft | Average Speed (kts) | Std Dev (kts) | Min Speed (kts) | Max Speed (kts) |
|---|---|---|---|---|
| B748 | 155 | 0 | 155 | 155 |
| B744 | 154 | 7 | 146 | 172 |
| MD11 | 151 | 7 | 128 | 170 |
| B738 | 149 | 10 | 71 | 169 |
| B739 | 148 | 7 | 129 | 166 |
| B764 | 147 | 11 | 128 | 164 |
| A321 | 144 | 8 | 126 | 162 |
| B753 | 144 | 7 | 131 | 161 |
| MD90 | 144 | 8 | 125 | 159 |
| MD83 | 143 | 11 | 128 | 161 |
| A343 | 142 | 3 | 138 | 145 |
| B763 | 141 | 8 | 104 | 163 |
| B77L | 140 | 5 | 130 | 154 |
| A333 | 140 | 2 | 138 | 141 |
| MD88 | 139 | 8 | 117 | 160 |
| GLF4 | 139 | 3 | 135 | 142 |
| B734 | 139 | 13 | 122 | 155 |
| DC10 | 138 | 5 | 124 | 150 |
| GALX | 137 | 0 | 137 | 137 |
| MD82 | 135 | 4 | 129 | 141 |
| E190 | 135 | 7 | 126 | 144 |
| E75L | 135 | 7 | 120 | 153 |
| CRJ9 | 135 | 9 | 110 | 152 |
| A320 | 135 | 7 | 114 | 153 |
| B712 | 135 | 9 | 114 | 154 |
| ASTR | 134 | 0 | 134 | 134 |
| B733 | 134 | 9 | 113 | 147 |
| B737 | 134 | 8 | 113 | 153 |
| CRJ2 | 133 | 8 | 117 | 147 |
| B757 | 132 | 0 | 132 | 132 |
| E170 | 132 | 7 | 110 | 149 |
| CRJ7 | 132 | 7 | 117 | 145 |
| A306 | 132 | 6 | 107 | 150 |
| B762 | 129 | 7 | 125 | 141 |
| A319 | 129 | 7 | 106 | 146 |

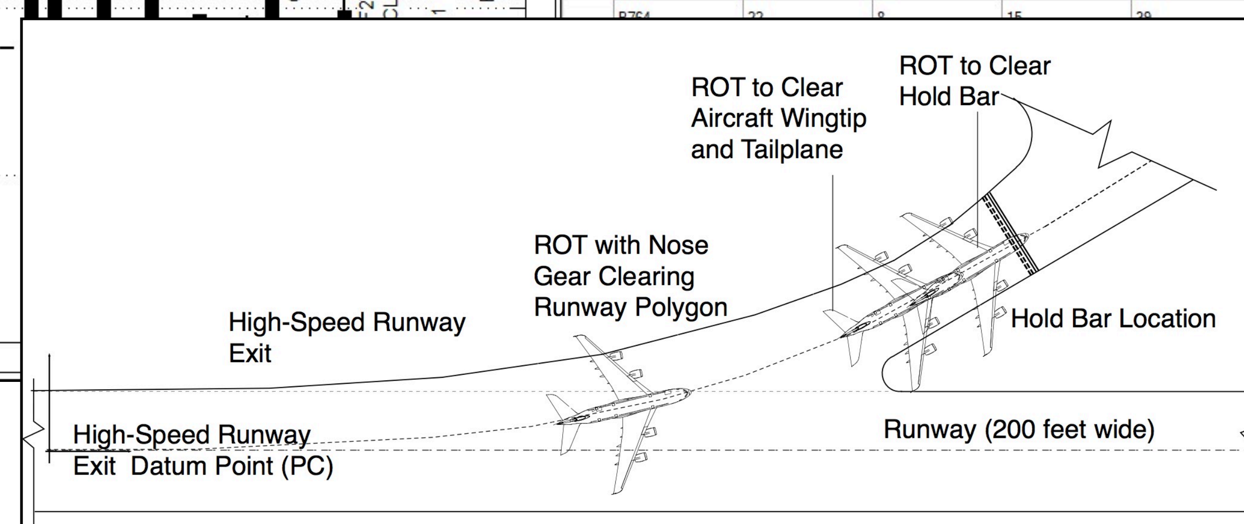
# Velocity Profiles by Airport and Aircraft



# Runway Exit Speeds at Point of Curvature




| Aircraft | Average Speed (kts) | Std Dev (kts) | Min Speed (kts) | Max Speed (kts) |
|---|---|---|---|---|
| LJ55 | 36 | 0 | 36 | 36 |
| E190 | 34 | 11 | 18 | 44 |
| CRJ9 | 31 | 9 | 13 | 45 |
| MD88 | 31 | 9 | 12 | 56 |
| MD90 | 30 | 8 | 17 | 50 |
| B712 | 29 | 9 | 12 | 54 |
| B733 | 29 | 7 | 16 | 45 |
| CRJ2 | 29 | 9 | 11 | 50 |
| B737 | 28 | 8 | 13 | 53 |
| CRJ7 | 27 | 10 | 11 | 46 |
| B739 | 27 | 6 | 14 | 48 |
| E75L | 26 | 6 | 19 | 41 |
| A320 | 26 | 8 | 10 | 55 |
| ASTR | 26 | 0 | 26 | 26 |
| E170 | 26 | 7 | 15 | 42 |
| B772 | 25 | 0 | 25 | 25 |
| B753 | 25 | 6 | 14 | 36 |
| A319 | 25 | 8 | 10 | 51 |
| B738 | 25 | 7 | 8 | 46 |
| A333 | 24 | 2 | 22 | 26 |
| A321 | 24 | 9 | 9 | 51 |
| B763 | 24 | 8 | 10 | 52 |
| B757 | 24 | 0 | 24 | 24 |
| B77L | 24 | 6 | 13 | 33 |
| GALX | 23 | 0 | 23 | 23 |
| B764 | [illegible] | [illegible] | [illegible] | [illegible] |



# Table Summary with Runway Occupancy and Percent of Aircraft Taking a Runway Exit

Landing Events Database - [ATL - 26L Runway Analysis]

- ATL
  - Airport
  - Runways
    - 08L
    - 08R
    - 09L
    - 09R
    - 10
    - 26L
    - 26R
    - 27L
    - 27R
    - 28
  - Raw Data
  - Statistics
- BDL
- BOS
- BWI
- CLE
- CLT
- DCA
- DEN
- DFW
- DTW
- EWR
- FLL
- HNL
- HOU
- IAD

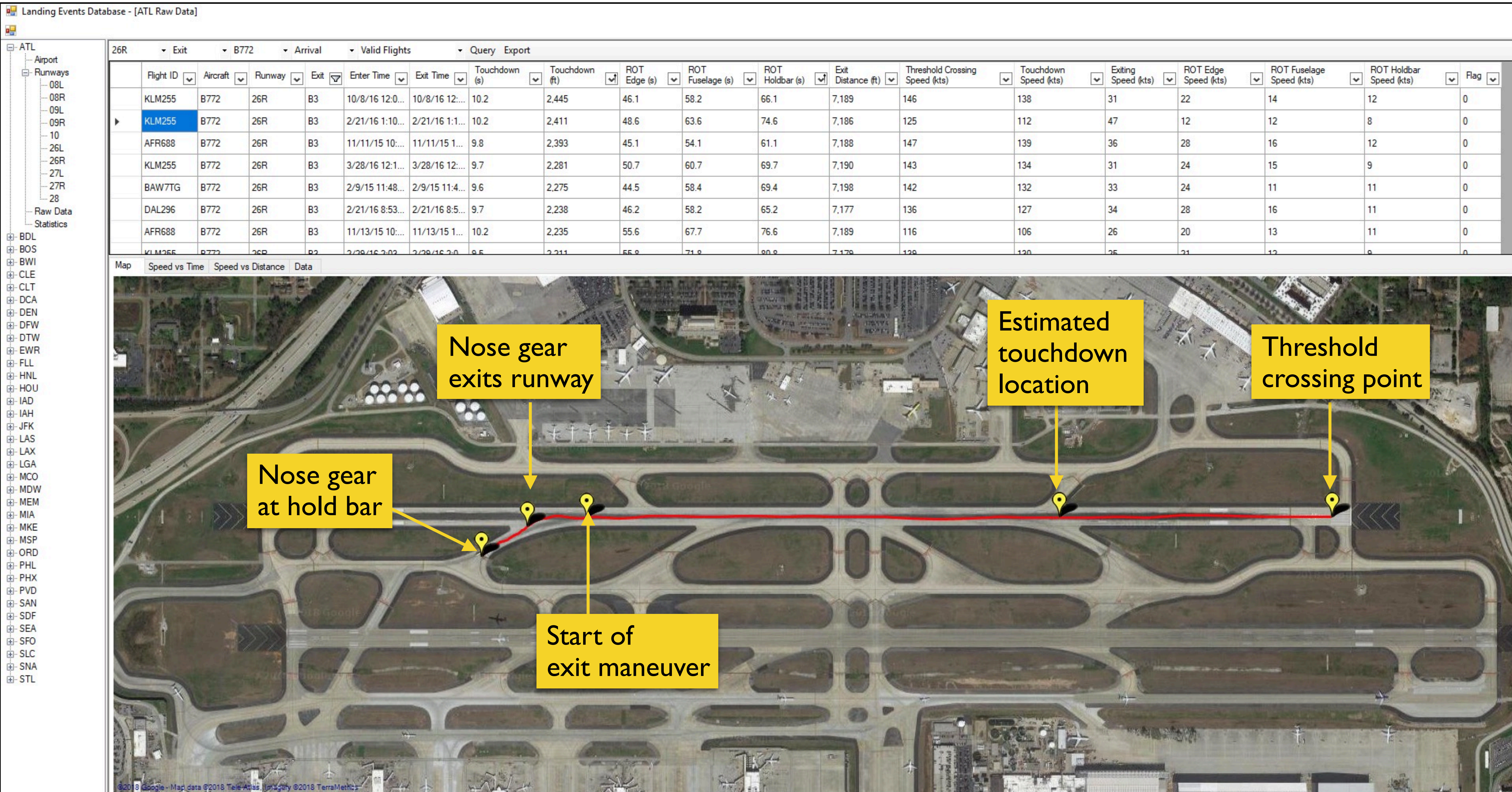
Aircraft Mix | ROT By Aircraft | ROT Distribution | ROT Table | Speed By Aircraft | Velocity Profiles | TD Location

ROT to Runway Edge | ROT Real | ROT to Holdbar

## ROT to Holdbar for ATL - 26L

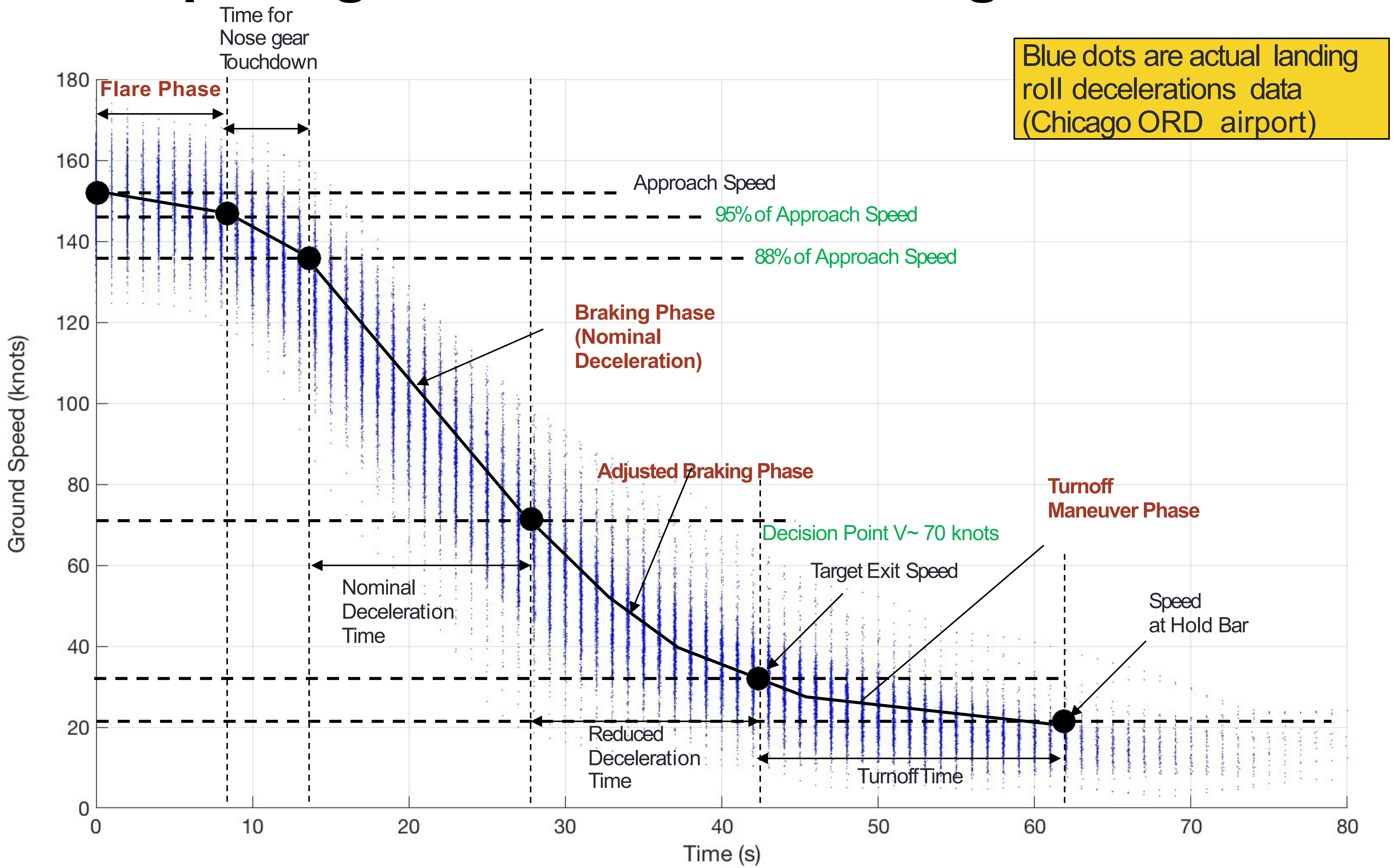
| aircraft_type | B10-S | B4 | B6 | C-L | C-R | D-L | D-R | E1 | E11 | E3 | E5 | E7 | H-L | H-R | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A306 | | 82.1s 4.3% | 73.6s 55.4% | 70.9s 0.7% | 60.8s 12.2% | | 56.6s 23.7% | | | | 78.1s 2.9% | 65.2s 0.7% | | | 68.4s |
| A310 | | | | | 58.2s 33.3% | | 66.7s 33.3% | | | 90.1s 33.3% | | | | | 71.7s |
| A319 | | | 81.5s 2.9% | 75.5s 1.1% | 70.4s 0.6% | 58.0s 2.3% | 60.9s 2.3% | 94.8s 2.3% | | 79.9s 38.3% | 71.7s 21.7% | 59.4s 27.4% | 105.3s 0.6% | 100.9s 0.6% | 72.1s |
| A320 | | | 63.8s 1.9% | 46.8s 1.0% | | 57.4s 1.9% | | 83.1s 3.8% | | 74.5s 45.2% | 72.9s 24.0% | 57.6s 21.2% | 103.9s 1.0% | | 70.3s |
| A321 | | | | 54.5s 2.0% | | | | 84.2s 2.0% | | 71.2s 63.3% | 69.8s 24.5% | 57.9s 6.1% | | 93.6s 2.0% | 70.4s |
| A333 | | | | | | | | | | 67.6s 100.0% | | | | | 67.6s |
| A343 | | | | | | | | | | 86.2s 100.0% | | | | | 86.2s |
| AEST | | | | 61.1s 50.0% | | | 87.4s 50.0% | | | | | | | | 74.3s |
| ASTR | | | 62.4s 100.0% | | | | | | | | | | | | 62.4s |
| B190 | | | 83.8s 50.0% | | | | 72.2s 50.0% | | | | | | | | 78.0s |
| B350 | | | | | | | 72.4s 100.0% | | | | | | | | 72.4s |
| B712 | | | 50.9s 1.6% | | | | | | | 74.9s 60.3% | 67.2s 14.3% | 54.5s 23.8% | | | 68.6s |
| B733 | | | | | | | | | | 75.1s 54.9% | 68.5s 11.8% | 56.9s 31.4% | | 104.7s 2.0% | 69.2s |

# Google Earth Viewport Functionality Includes Pan/Zoom Functions




| Flight ID | Aircraft | Runway | Exit | Enter Time | Exit Time | Touchdown (s) | Touchdown (ft) | ROT Edge (s) | ROT Fuselage (s) | ROT Holdbar (s) | Exit Distance (ft) | Threshold Crossing Speed (kts) | Touchdown Speed (kts) | Exiting Speed (kts) | ROT Edge Speed (kts) | ROT Fuselage Speed (kts) | ROT Holdbar Speed (kts) | Flag |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| KLM255 | B772 | 26R | B3 | 10/8/16 12:0... | 10/8/16 12:... | 10.2 | 2,445 | 46.1 | 58.2 | 66.1 | 7,189 | 146 | 138 | 31 | 22 | 14 | 12 | 0 |
| KLM255 | B772 | 26R | B3 | 2/21/16 1:10... | 2/21/16 1:1... | 10.2 | 2,411 | 48.6 | 63.6 | 74.6 | 7,186 | 125 | 112 | 47 | 12 | 12 | 8 | 0 |
| AFR688 | B772 | 26R | B3 | 11/11/15 10:... | 11/11/15 1... | 9.8 | 2,393 | 45.1 | 54.1 | 61.1 | 7,188 | 147 | 139 | 36 | 28 | 16 | 12 | 0 |
| KLM255 | B772 | 26R | B3 | 3/28/16 12:1... | 3/28/16 12:... | 9.7 | 2,281 | 50.7 | 60.7 | 69.7 | 7,190 | 143 | 134 | 31 | 24 | 15 | 9 | 0 |
| BAW7TG | B772 | 26R | B3 | 2/9/15 11:48... | 2/9/15 11:4... | 9.6 | 2,275 | 44.5 | 58.4 | 69.4 | 7,198 | 142 | 132 | 33 | 24 | 11 | 11 | 0 |
| DAL296 | B772 | 26R | B3 | 2/21/16 8:53... | 2/21/16 8:5... | 9.7 | 2,238 | 46.2 | 58.2 | 65.2 | 7,177 | 136 | 127 | 34 | 28 | 16 | 11 | 0 |
| AFR688 | B772 | 26R | B3 | 11/13/15 10:... | 11/13/15 1... | 10.2 | 2,235 | 55.6 | 67.7 | 76.6 | 7,189 | 116 | 106 | 26 | 20 | 13 | 11 | 0 |

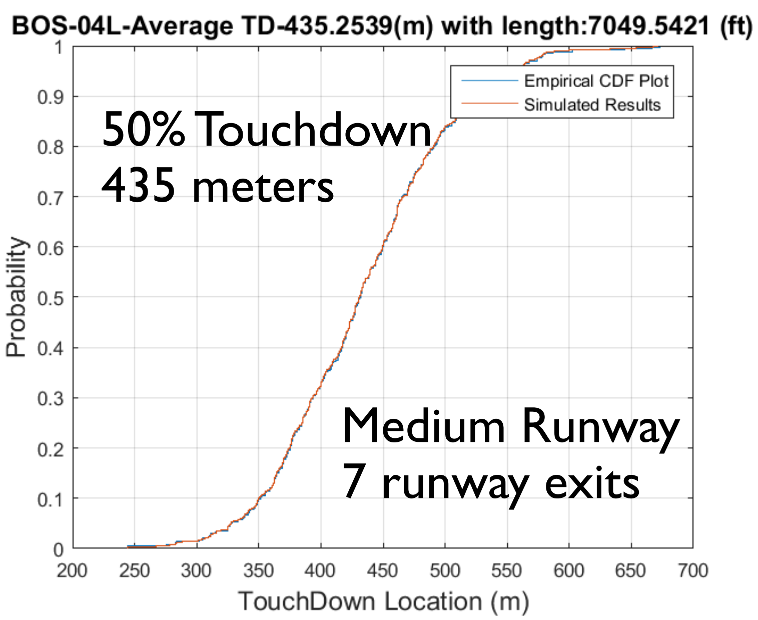
# Developed Algorithms to Predict Landing Roll Parameters

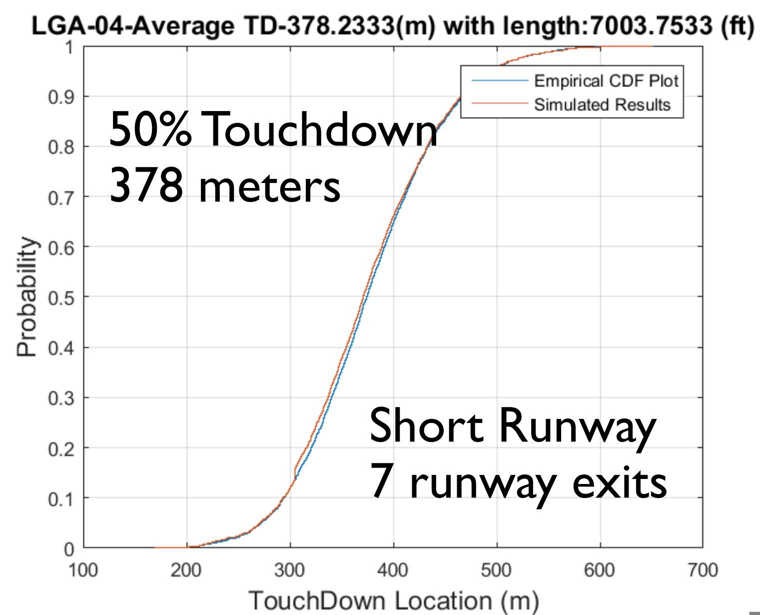


# Validation of Landing Parameters using Video Data Collected at Three Airports

| | DCA Video Data Collection | | | | Estimate from ASDE-X | | Error |
|---|---|---|---|---|---|---|---|
| Aircraft Type | Touchdown Distance (m) | Touchdown Distance STD (m) | Runway Occupancy Time (s) | Time Between Main gear and Nose Gear Touchdown (s) | Touchdown Distance (m) | Touchdown Distance STD (m) | Percent Difference (%) |
| Boeing 737-800 | 390 | 65 | 44.9 | 2.7 | 389 | 66 | 0.26 |
| Embraer 175 | 384 | 69 | 44.7 | 3.2 | 373 | 65 | 2.86 |
| Embraer 135 | 343 | 80 | 44.1 | 3.3 | 340 | 63 | 0.87 |

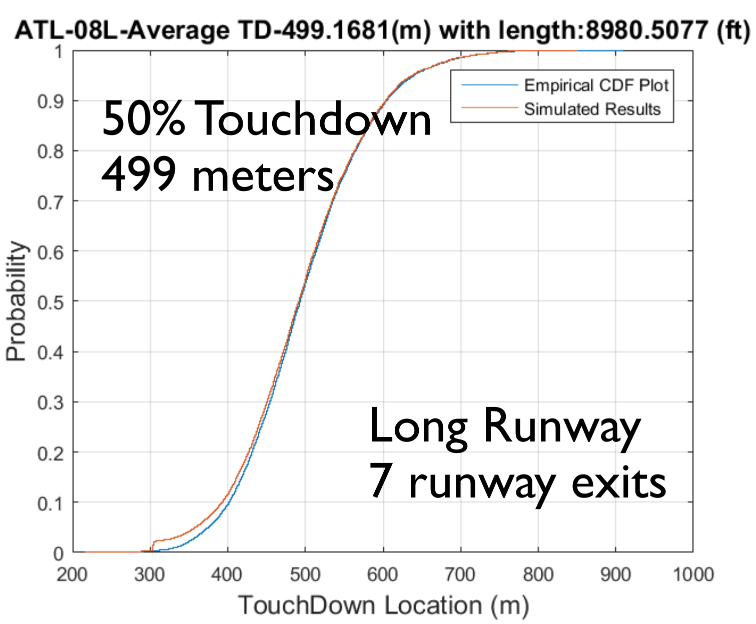

# Good Correlation Between Estimated Touchdown Location and Simulated Results: Four Runway Clusters Shown

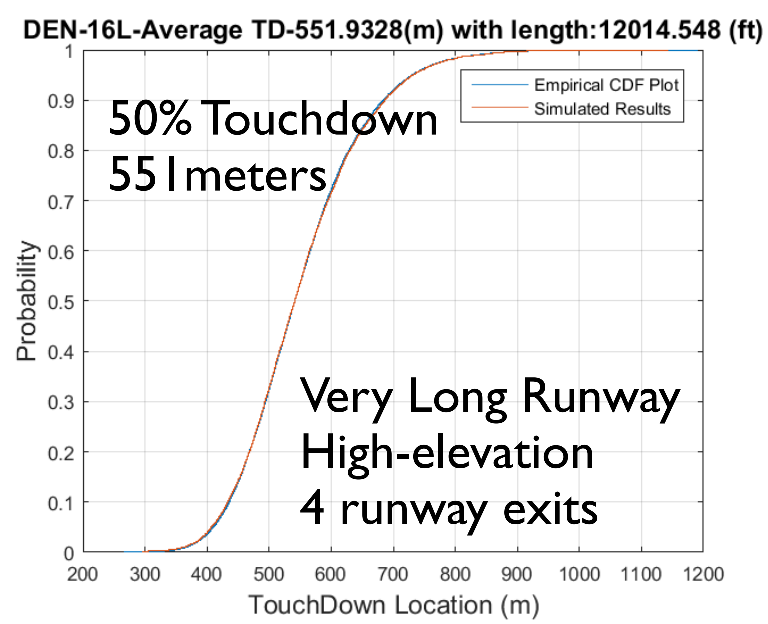


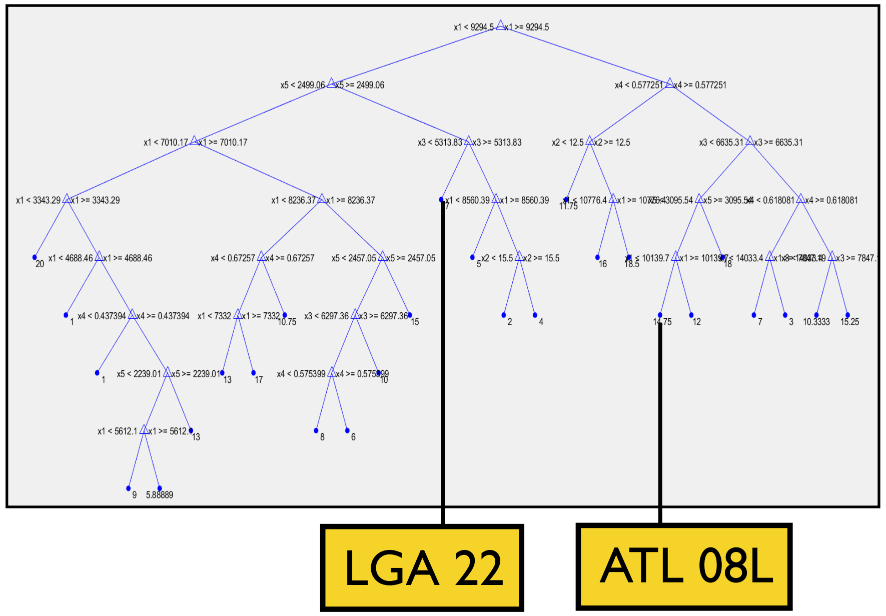





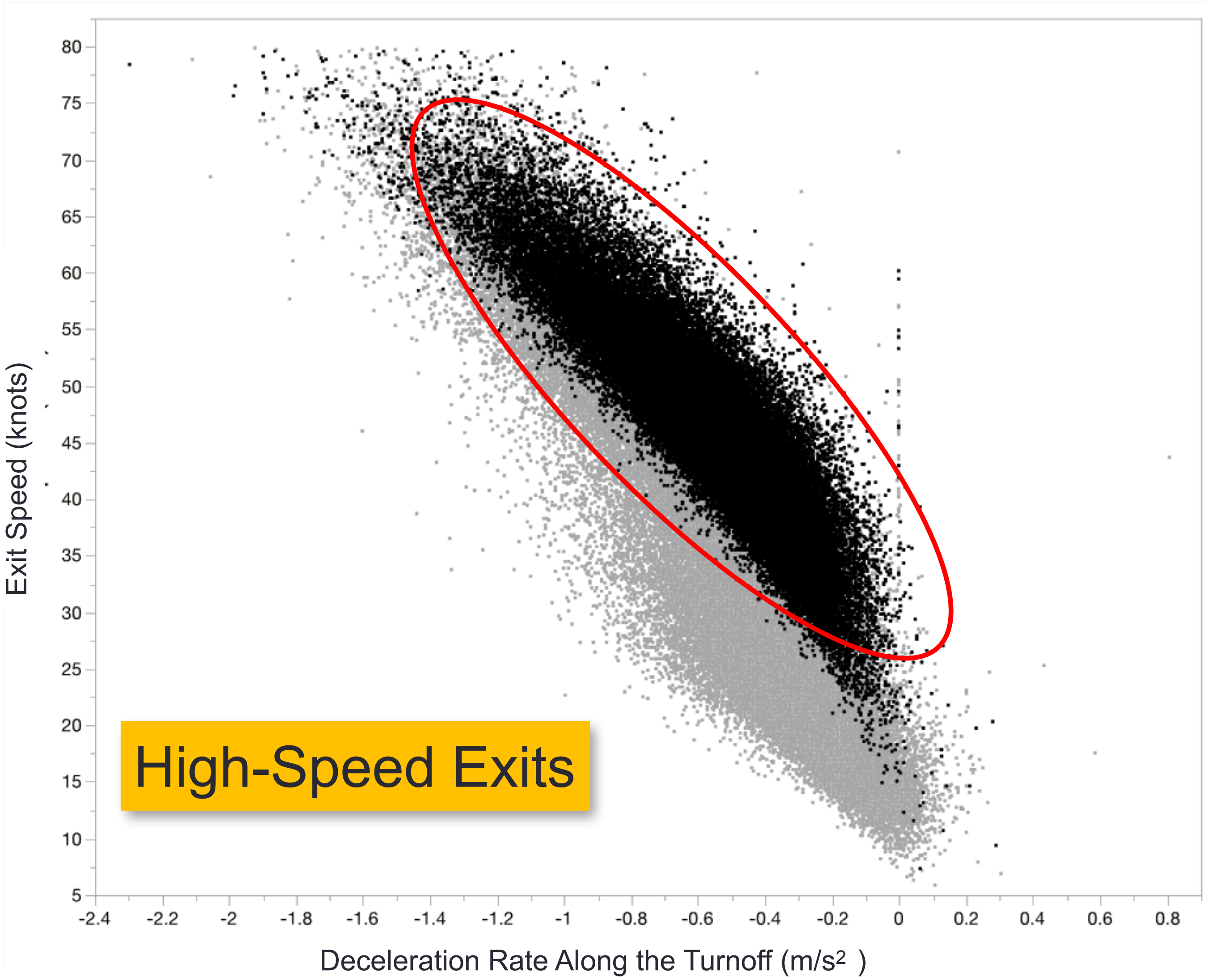
## Boeing 737-700 Data



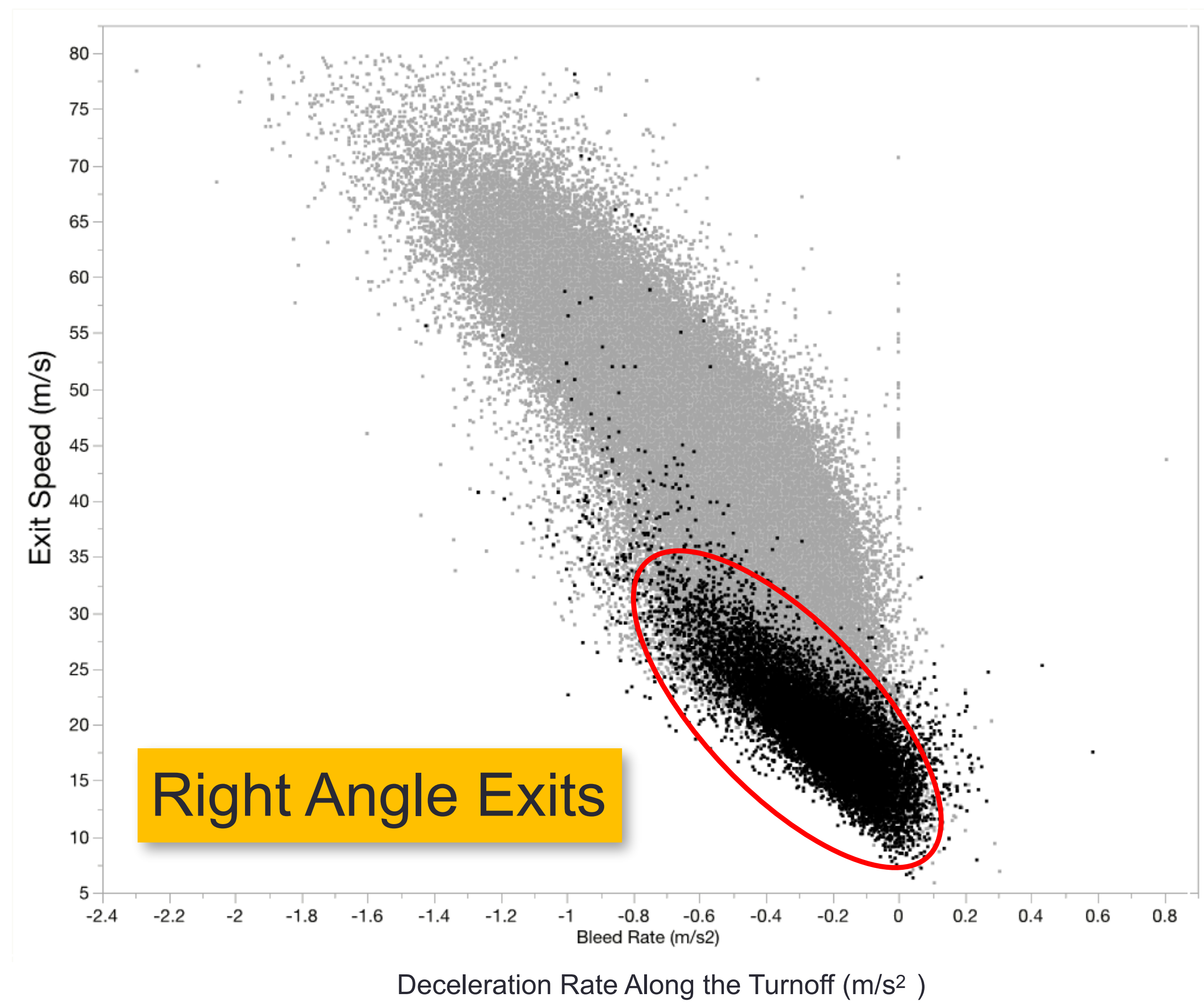



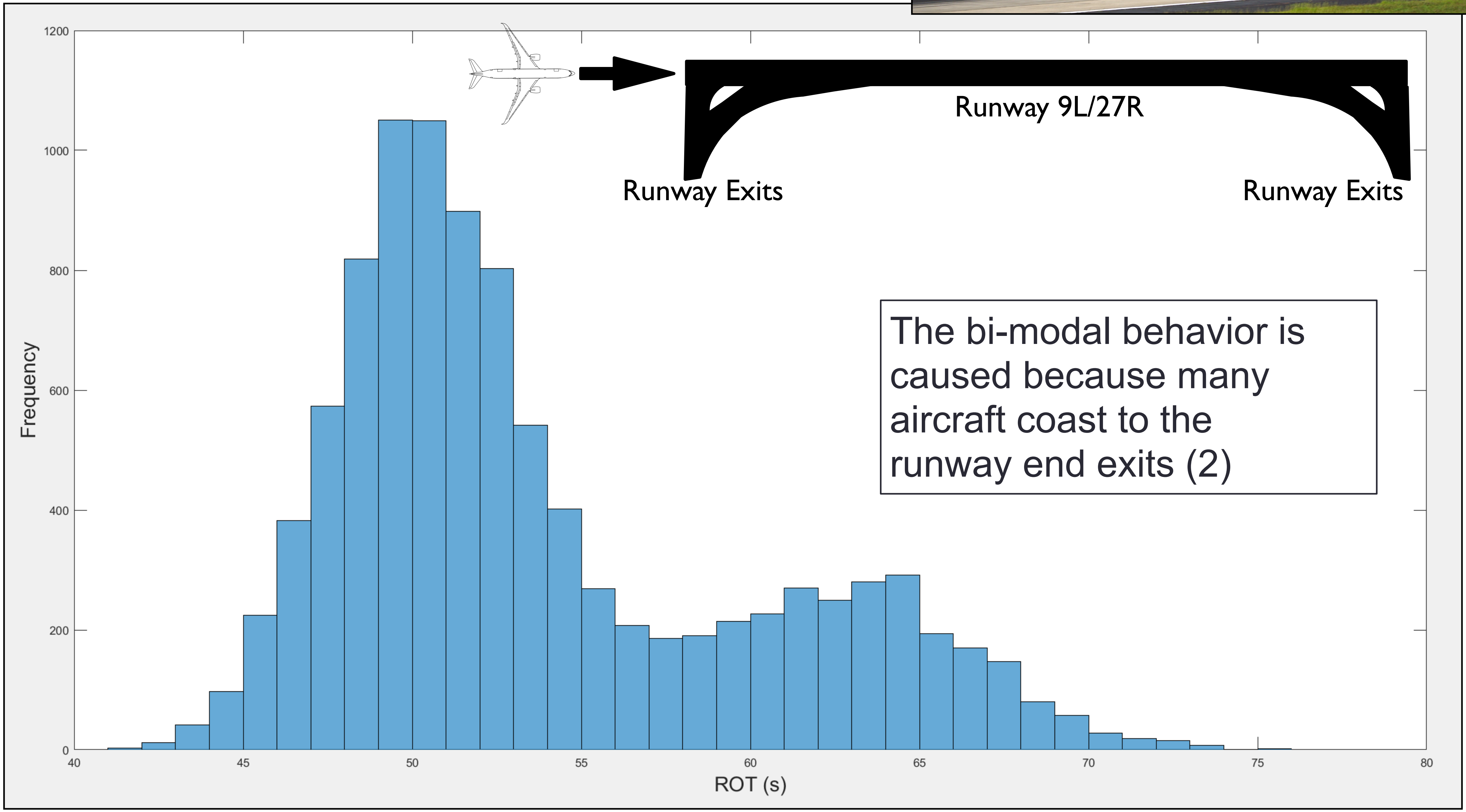
# Deceleration Rates Along the Turnoff and Exit Speed at the Point of Curvature are Correlated



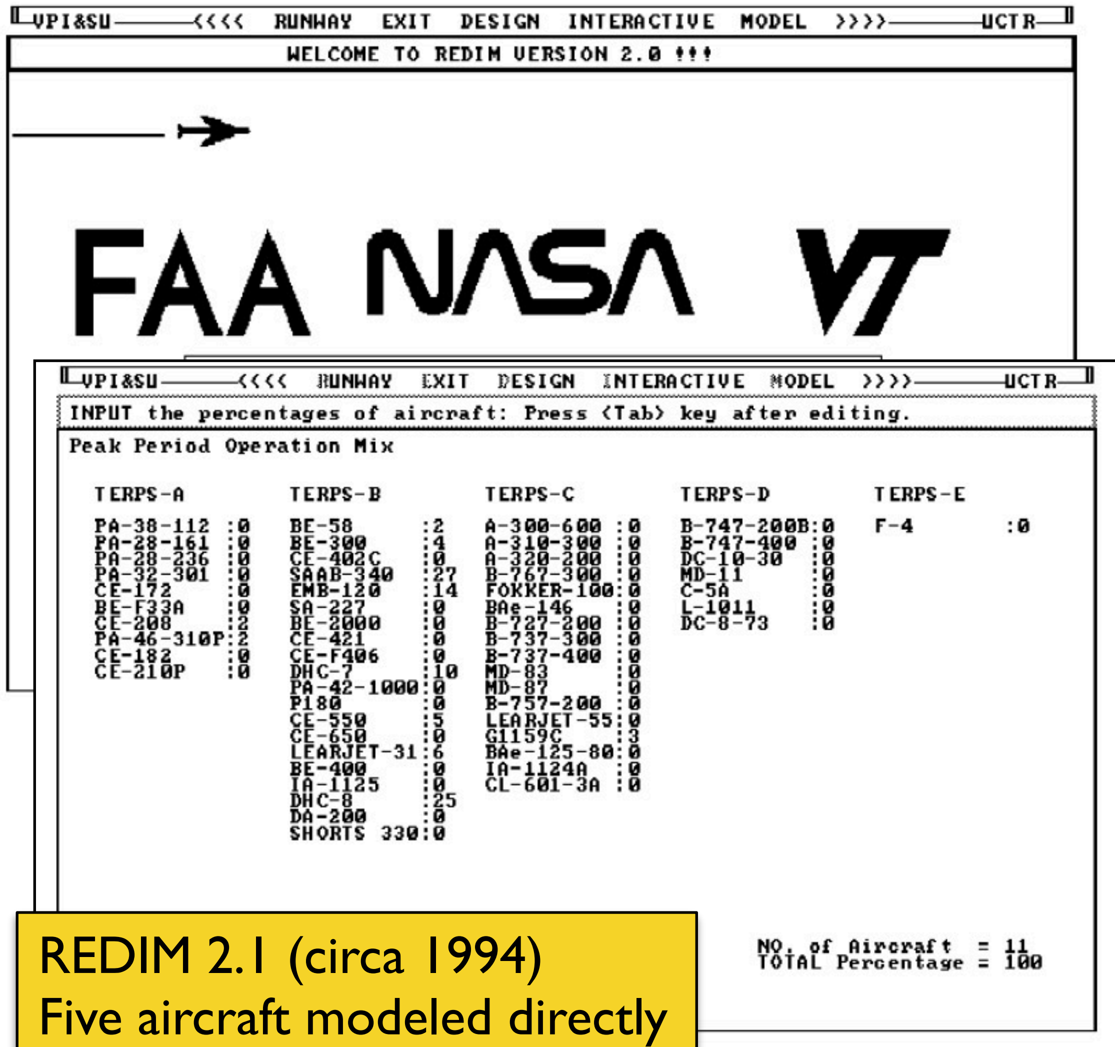

889,039 records
for ADG-III



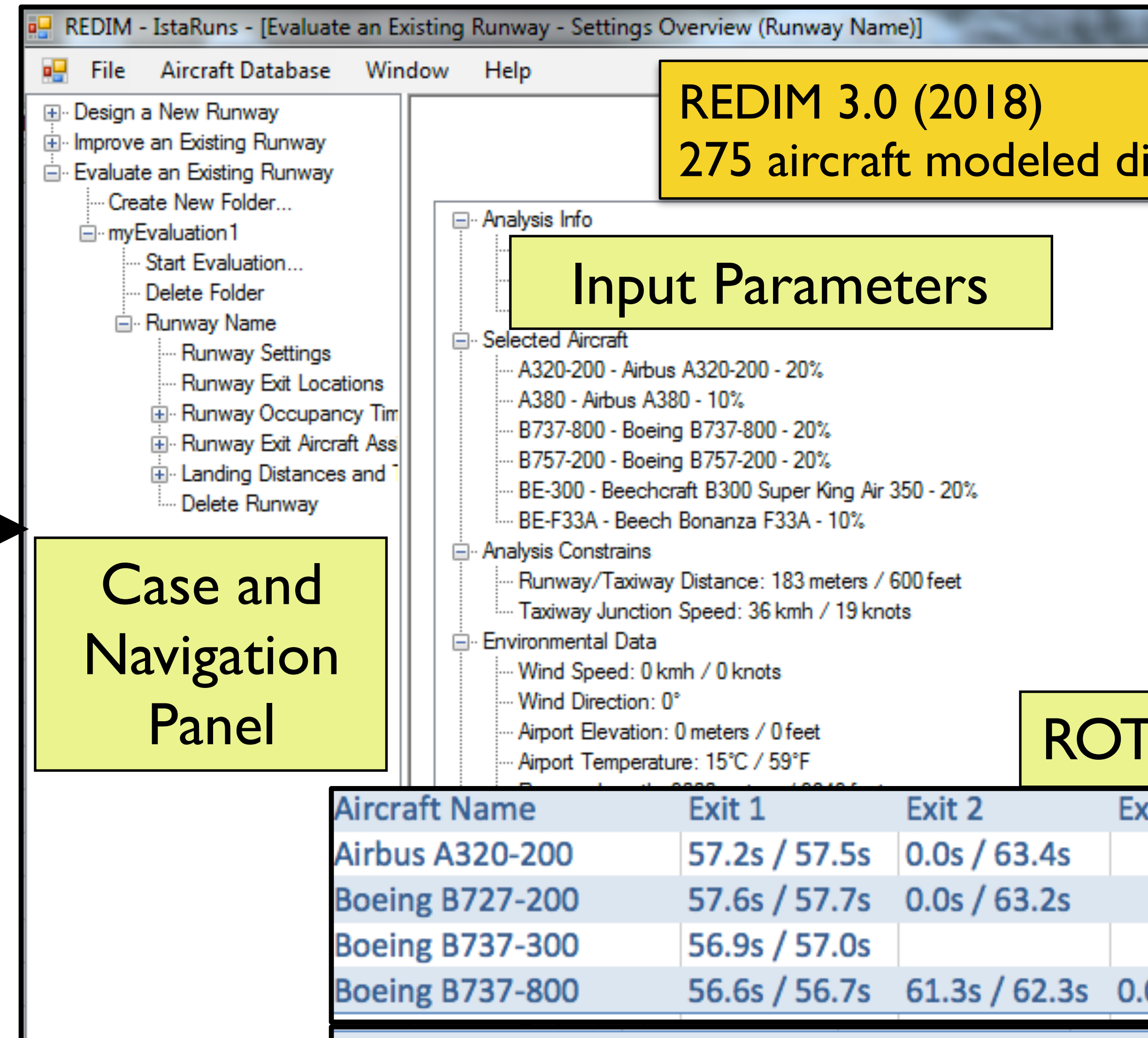
# Airbus A321 Monte Carlo Simulation of Chicago O'Hare Runway 9L



# Runway Exit Design Interactive Model (REDIM 3)




REDIM 2.1 (circa 1994)
Five aircraft modeled directly
45 aircraft modeled indirectly




REDIM 3.0 (2018)
275 aircraft modeled directly

Input Parameters

Case and Navigation Panel

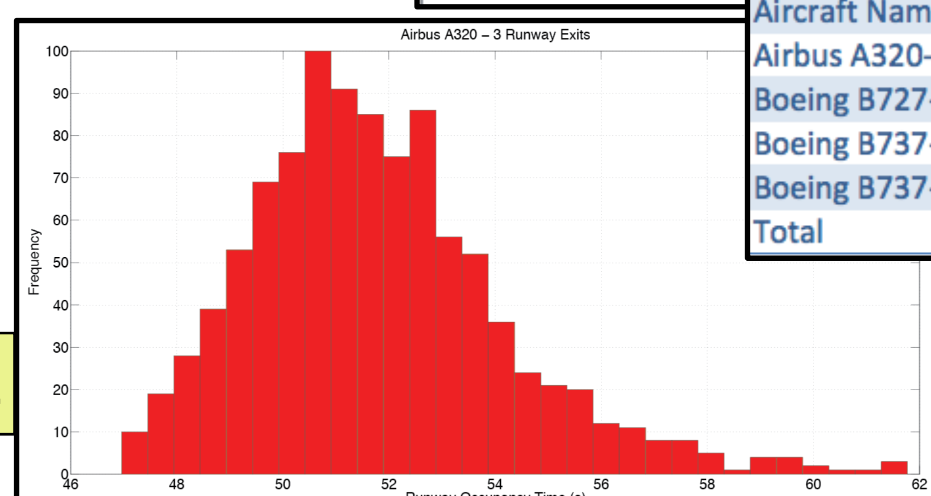
ROT Table

| Aircraft Name | Exit 1 | Exit 2 | Exit 3 |
|---|---|---|---|
| Airbus A320-200 | 57.2s / 57.5s | 0.0s / 63.4s | |
| Boeing B727-200 | 57.6s / 57.7s | 0.0s / 63.2s | |
| Boeing B737-300 | 56.9s / 57.0s | | |
| Boeing B737-800 | 56.6s / 56.7s | 61.3s / 62.3s | 0.0s / 85.0s |

| Aircraft Name | Exit 1 | Exit 2 | Exit 3 |
|---|---|---|---|
| Airbus A320-200 | 6.0% / 2.7% | 0.5% / 3.6% | 0.0% / 0.2% |
| Boeing B727-200 | 1.7% / 0.7% | 0.3% / 1.2% | 0.0% / 0.1% |
| Boeing B737-300 | 2.0% / 1.8% | 0.0% / 0.2% | |
| Boeing B737-800 | 20.1% / 1.9% | 18.5% / 25.5% | 0.9% / 12.2% |
| Total | 29.8% / 7.0% | 19.3% / 30.5% | 0.9% / 12.5% |

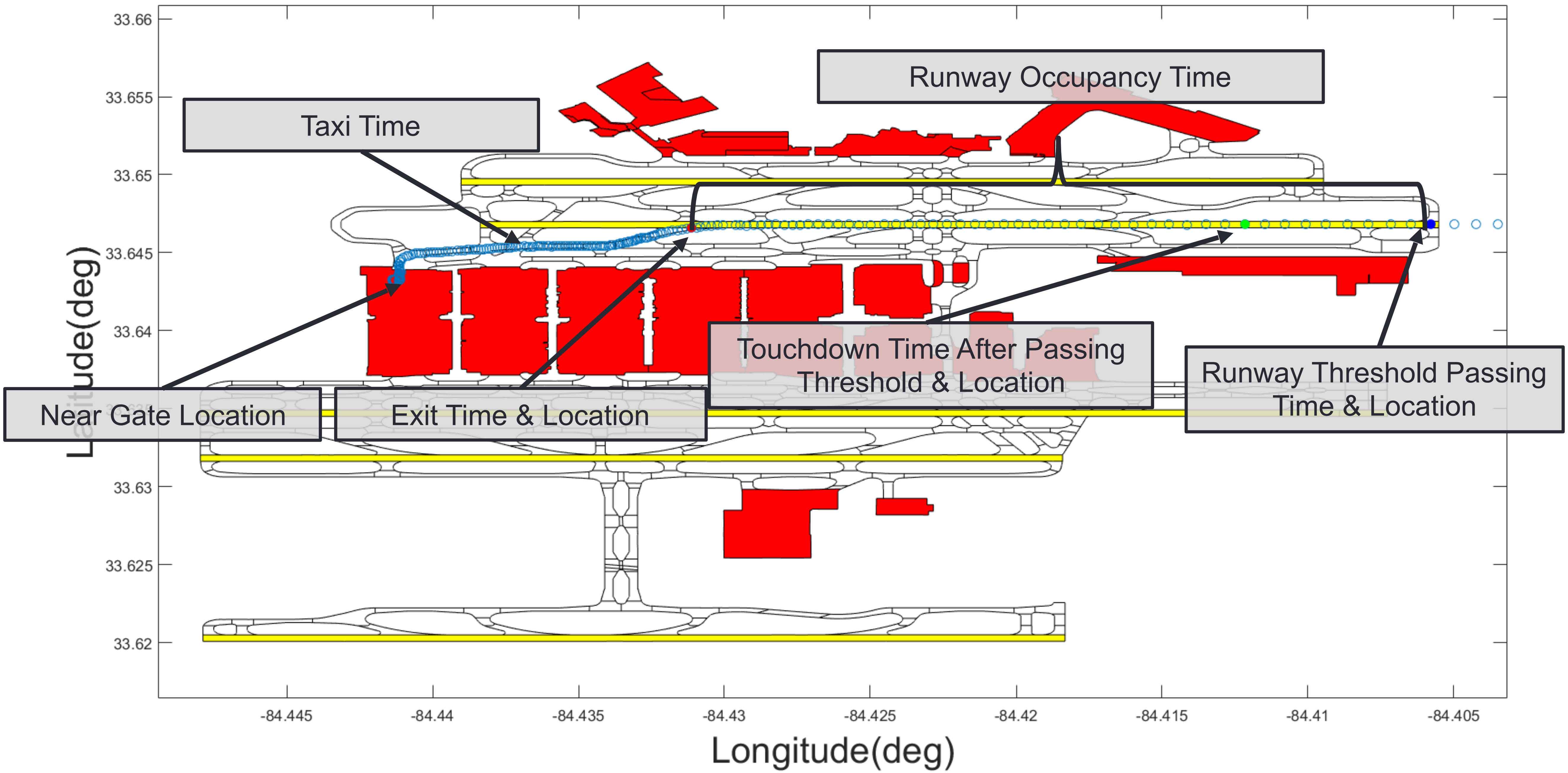
Exit Assignment Table

ROT Plot



# Taxi Event Extraction Tool from ASDE-X (non-adaptation) Surveillance for Surface Performance Evaluation

# Evaluate Unimpeded Taxi In/out Times at Airports using ASDE-X Surveillance Data




Flight arrival extraction events

# Summary of Processed Files

Table 1 Summary of ASDE-X Number of Operations

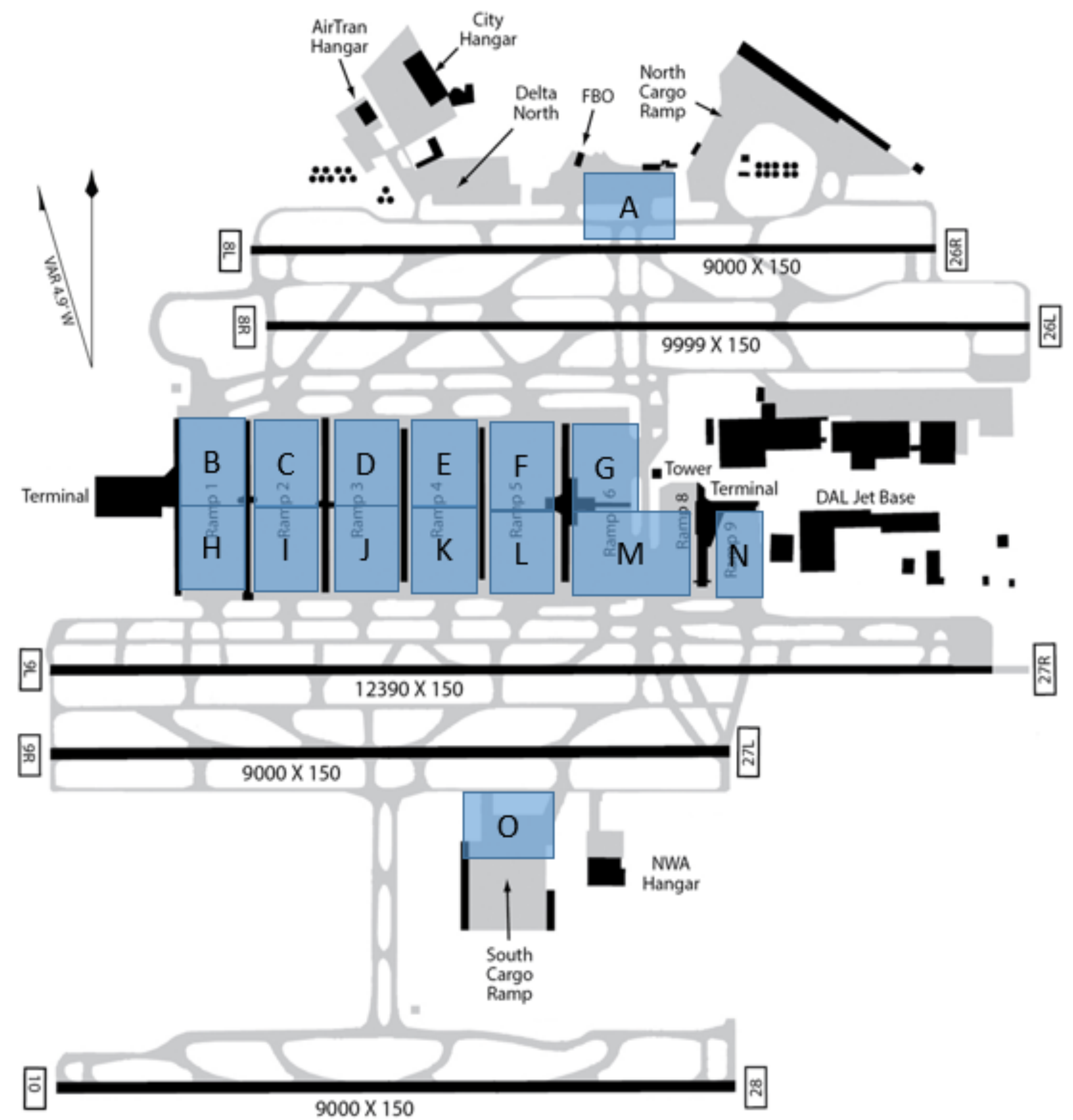
| Airport Name | # Parsed Arrival Flights | % Arrivals with All Events | # Parsed Departure Flights | % Departures with All Events |
|---|---|---|---|---|
| ATL | 38,973 | 98.4% | 37,185 | 98.3% |
| CLT | 22,786 | 98.3% | 21,666 | 96.9% |
| DEN | 24,015 | 87.0% | 22,188 | 85.0% |
| IAH | 22,414 | 93.0% | 22,048 | 92.4% |
| JFK | 18,465 | 85.0% | 17,011 | 81.0% |
| ORD | 39,053 | 97.6% | 37,899 | 94.1% |

# Methods for Estimating Unimpeded Taxi Time

**1- FAA Regression (NomTo):** A linear regression is used to estimate the taxi times during hours of no congestion

**2- 5th-15th Percentile:** Flights with the same runway and gate are grouped together. The average of the taxi times between 5th and 15th percentile are considered as the unimpeded taxi time for each group cluster

**3- Waiting Method:** Aircraft time taxiing below 3 m/s (~6 knots) is recorded and the cumulative waiting time is considered as delay time

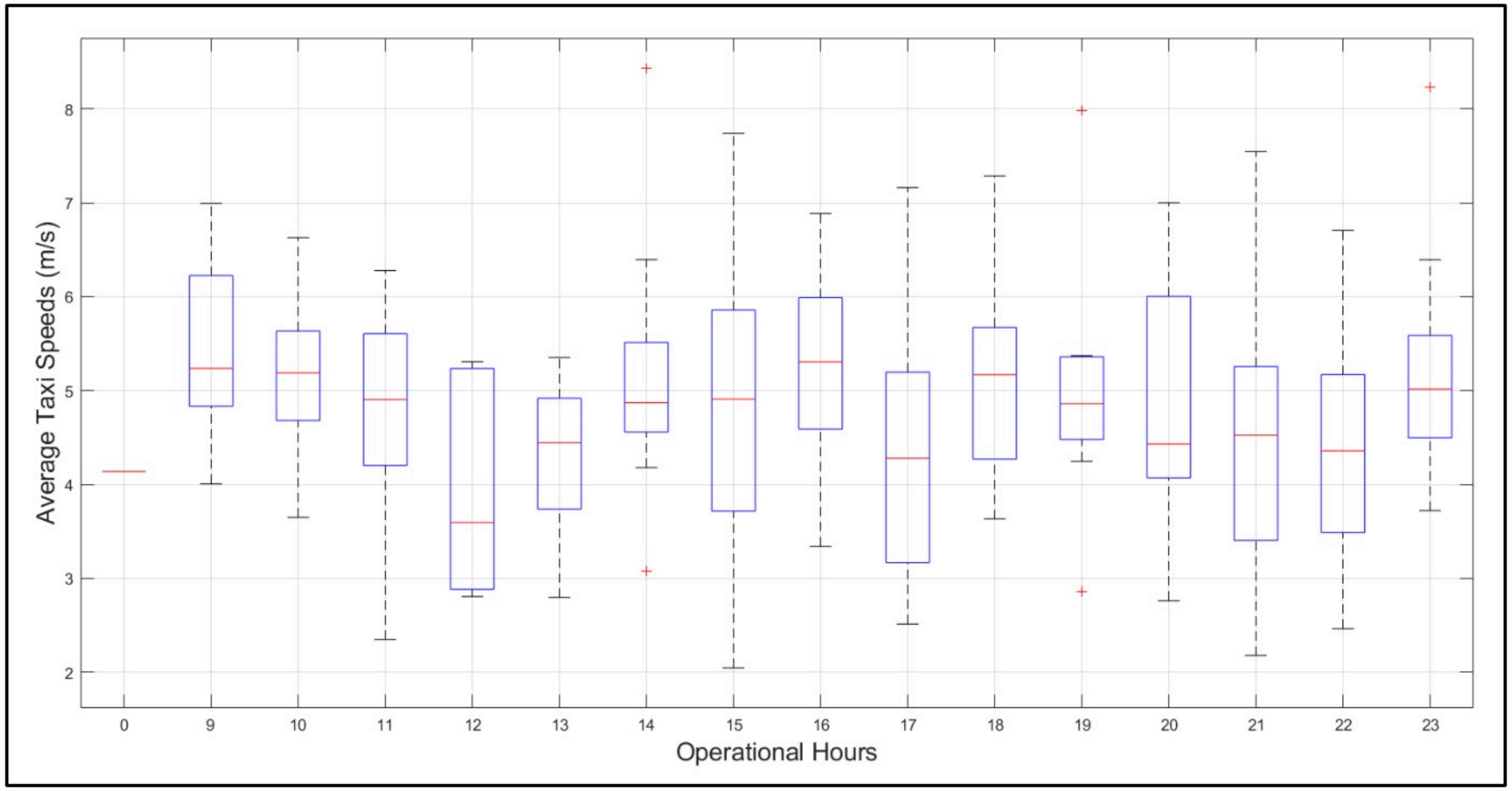


# Unimpeded Taxi-Out Time Results

Average Departure Taxi-Out Unimpeded Times

| Airport | FAA Regression (NomTo) | 5th- 15th Percentile | Waiting Method |
|---|---|---|---|
| ATL | 13.0 | 11.7 | 11.6 |
| CLT | 12.2 | 12.1 | 12.7 |
| DEN | 11.3 | 10.0 | 11.7 |
| IAH | 11.4 | 11.7 | 12.1 |
| JFK | 17.8 | 17.3 | 17.3 |
| ORD | 11.7 | 12.3 | 11.5 |

Average Taxing Speed of Departure Flights from Gate Group A to Runway 18C at CLT for Different Operational Hours (**Waiting Method**)



# Unimpeded Taxi-In Time Results

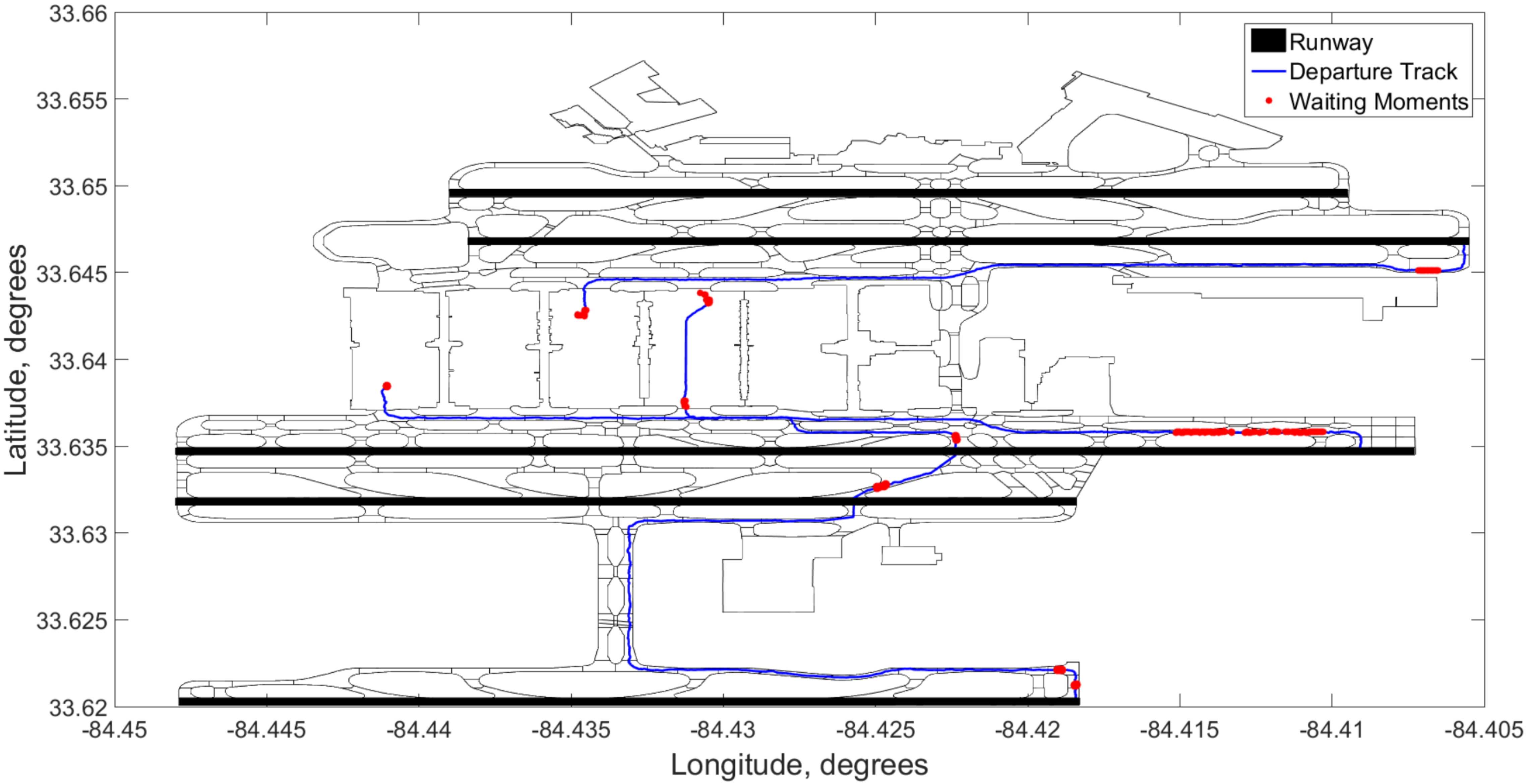
Average Arrival Taxi-In Unimpeded Times (minutes)

| Airport | FAA Regression (NomTo) | 5th- 15th Percentile | Waiting Method |
|---|---|---|---|
| ATL | 6.8 | 5.6 | 6.2 |
| CLT | 5.7 | 6.7 | 7.6 |
| DEN | 6.3 | 5.6 | 6.3 |
| IAH | 5.1 | 5.1 | 6.3 |
| JFK | 7.2 | 5.3 | 7.5 |
| ORD | 5.8 | 7.7 | 8.7 |

Average Calculated Delay for Arrival Flights (minutes)

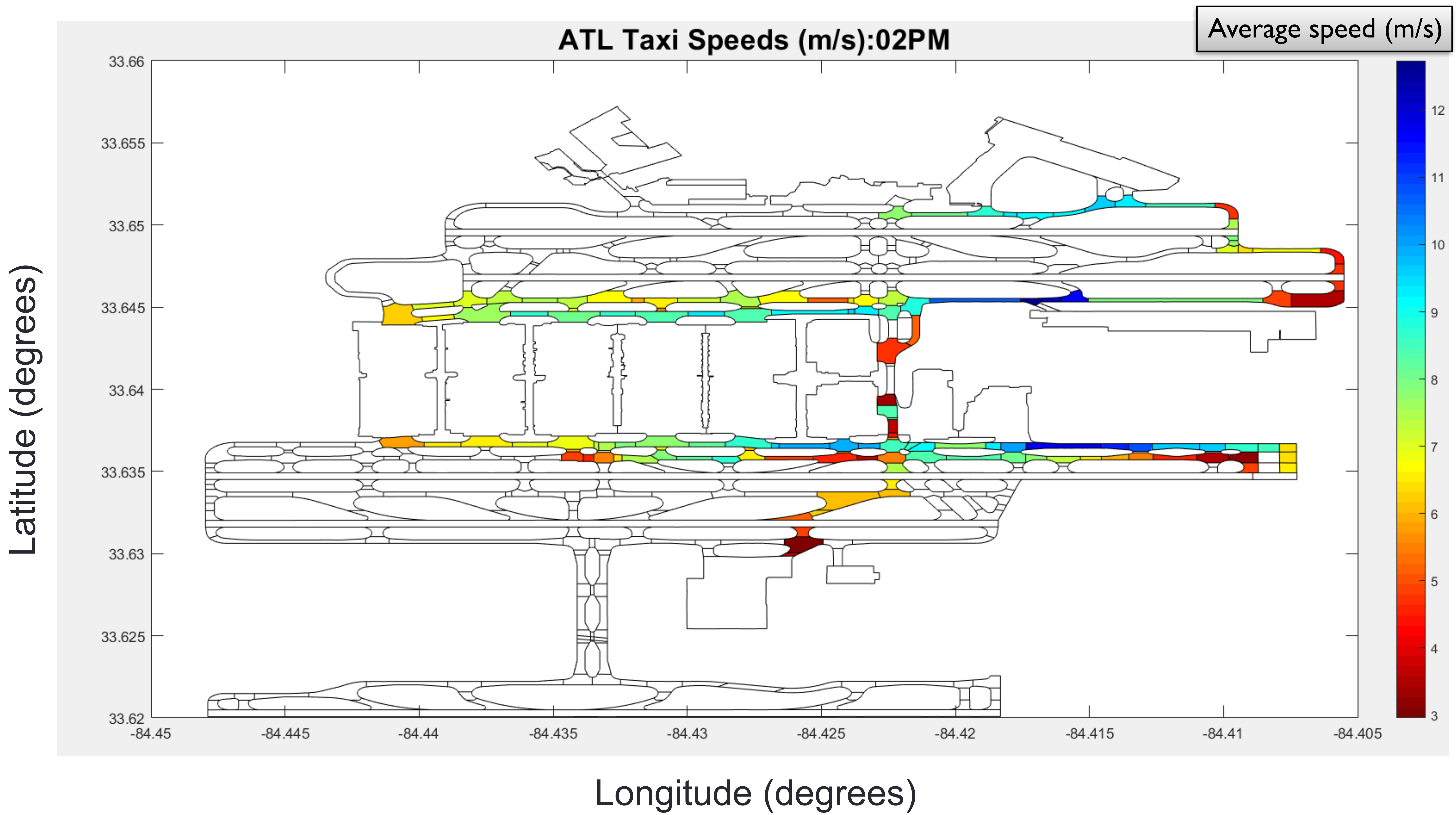
| Airport | FAA Regression (NomTo) | 5th- 15th Percentile | Waiting Method |
|---|---|---|---|
| ATL | 1.6 | 2.58 | 1.53 |
| CLT | 5.8 | 4.9 | 3.8 |
| DEN | 1.55 | 2.2 | 1.1 |
| IAH | 3.6 | 3.6 | 1.5 |
| JFK | 2.3 | 4.1 | 1.4 |
| ORD | 6.6 | 4.7 | 3 |

# Spatial Analysis of Runway and Taxi Data

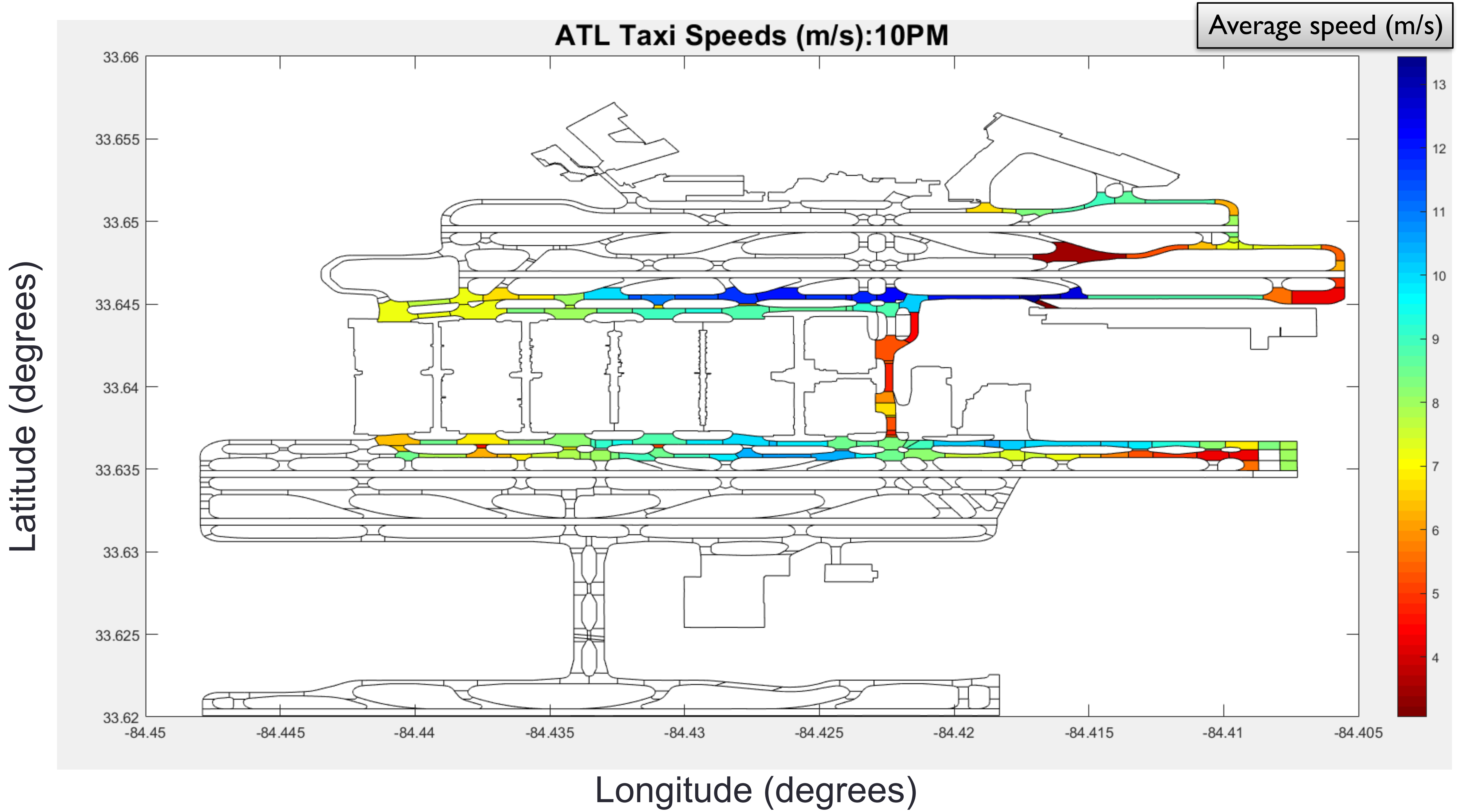


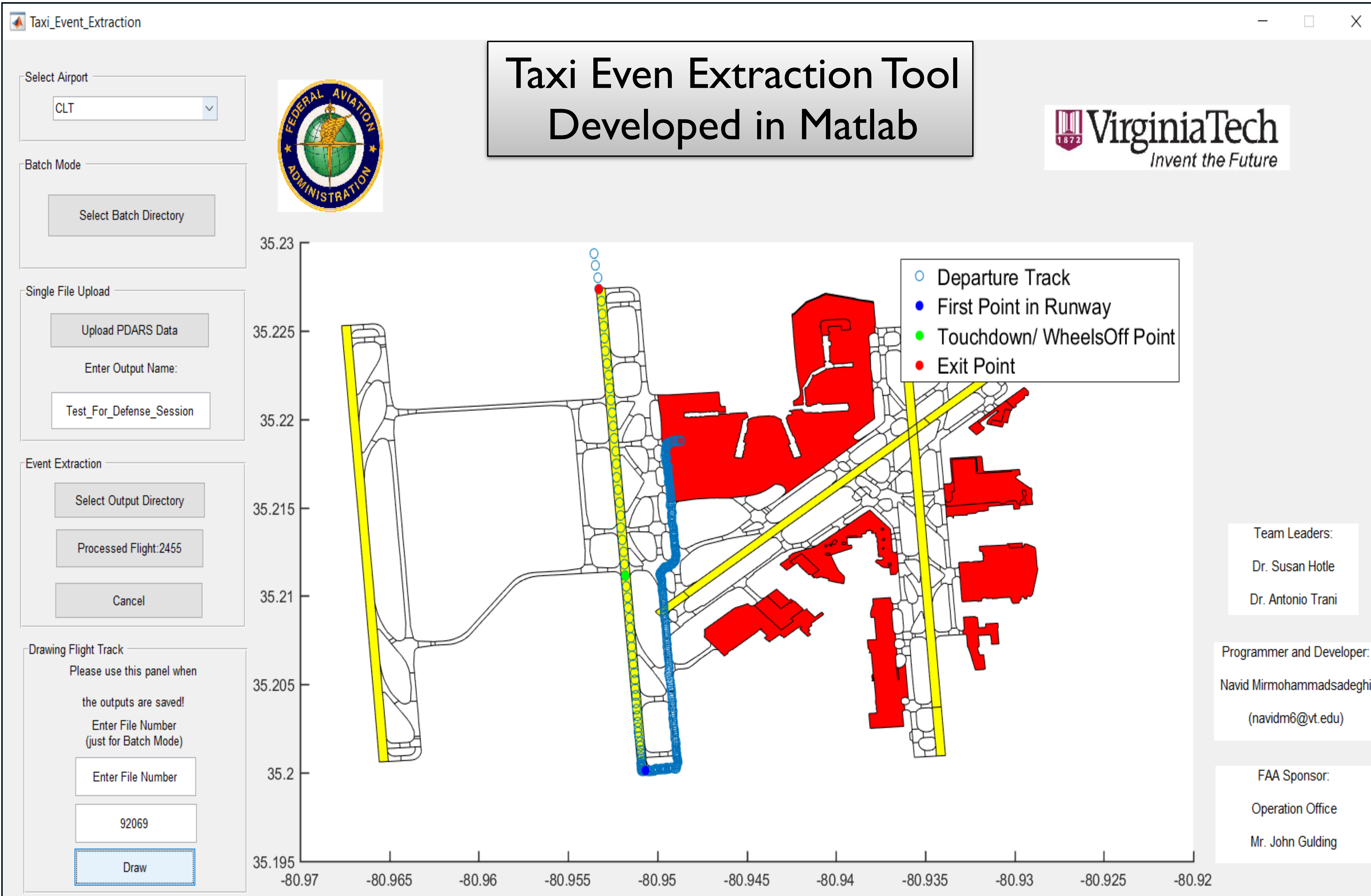

* Waiting moments = Traveling at <3 m/s

# Atlanta Airport Taxiway Speed Map at 2 PM



# Atlanta Airport Taxiway Speed Map at 10 PM




Taxi_Event_Extraction
Taxi Even Extraction Tool
Developed in Matlab
FEDERAL AVIATION ADMINISTRATION
VirginiaTech Invent the Future
Select Airport
CLT
Batch Mode
Select Batch Directory
Single File Upload
Upload PDARS Data
Enter Output Name:
Test_For_Defense_Session
Event Extraction
Select Output Directory
Processed Flight:2455
Cancel
Drawing Flight Track
Please use this panel when
the outputs are saved!
Enter File Number
(just for Batch Mode)
Enter File Number
92069
Draw
Departure Track
First Point in Runway
Touchdown/ WheelsOff Point
Exit Point
35.23
35.225
35.22
35.215
35.21
35.205
35.2
35.195
-80.97
-80.965
-80.96
-80.955
-80.95
-80.945
-80.94
-80.935
-80.93
-80.925
-80.92
Team Leaders:
Dr. Susan Hotle
Dr. Antonio Trani
Programmer and Developer:
Navid Mirmohammadsadeghi
(navidm6@vt.edu)
FAA Sponsor:
Operation Office
Mr. John Gulding

# Conclusions

- Three computer products developed to help FAA decision makers study and analyze large amounts of airport surface data
  - **Landing events database** contains runway occupancy times and could help in runway exit evaluation and design initiatives
  - **Runway exit design model** is a tool to optimize the location of runway exits
  - **Taxi event extraction tool** for surface performance evaluation
- NEXTOR II universities can produce **ready-to-use** tools and models for various FAA sponsors and industry

# Backup Slides

# Modeling Challenges: Pilot Motivational Practices