Aircraft Noise Abatement Procedure Modeling and Validation ASCENT 044

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Project 044

Aircraft Noise Abatement Procedure Modeling and Validation

Massachusetts Institute of Technology
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PM: Joe DiPardo, Chris Dorbian, FAA
Cost Share Partner(s): Massachusetts Port Authority

Objective:

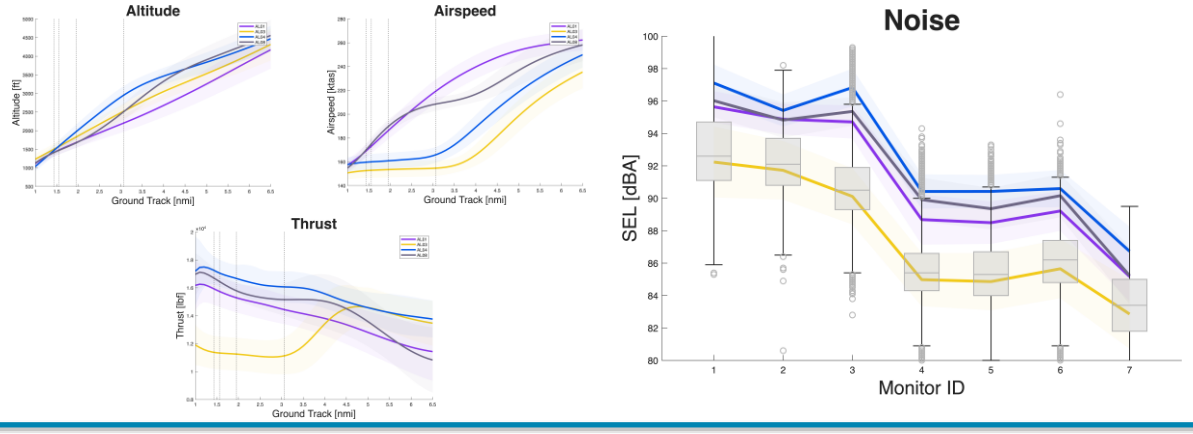
To utilize empirical noise data to develop data-based/learned noise models and validate and improve both existing noise models and advanced operational flight procedure design

Project Benefits:

Aircraft states, performance, and noise abatement flight procedures have been modeled and assessed through ASCENT projects 11 and 23. This project will validate and improve those models and provide insight into the modeling of noise abatement procedures like delayed deceleration approaches

Research Approach:

Noise based on radar and weather data is modeled and compared to airport noise monitor data for validation. Factors contributing to variation in noise monitor recordings are identified via data-based/machine learning techniques



Major Accomplishments (to date):

- Demonstrated methodology to relate aircraft, operational parameters, and weather to monitor recordings using ADS-B, NOAA Rapid Refresh data, and performance models to estimate weight and thrust
- Correlated departure and approach trajectories to monitor recordings for seven aircraft types over 3 years of data at KSEA ,2 years at KBOS, and 3 years at SNA
- Developed and published methodology to estimate takeoff and landing weight using a speed-based approach
- Validated noise and fuel burn benefits from RNAV procedures developed by A23 at BOS
- Identified differences in airline flight procedures, flight conditions and environmental factors which impact observed noise
- Identified individual aircraft variance by identifying outliers of individual aircraft tail numbers

Future Work / Schedule:

- Expand analysis of current dataset to identify factors driving loud and quiet outliers.
- Analyze datasets from additional airport locations, months, and aircraft types
- Assess implications of results of the design of noise abatement procedures

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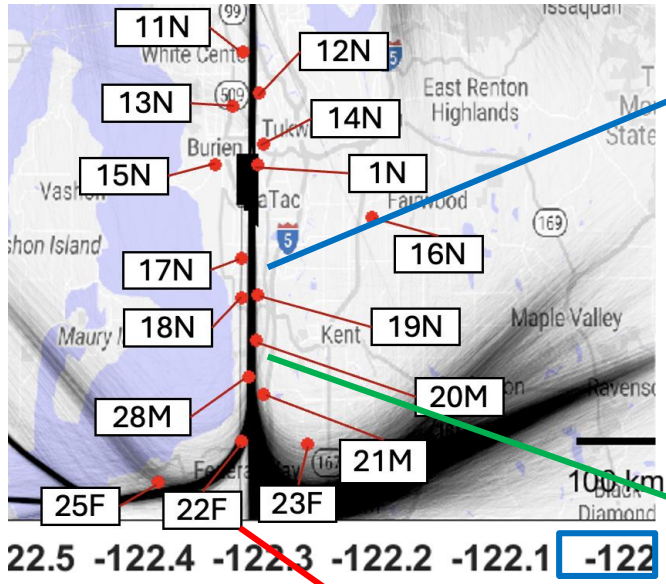
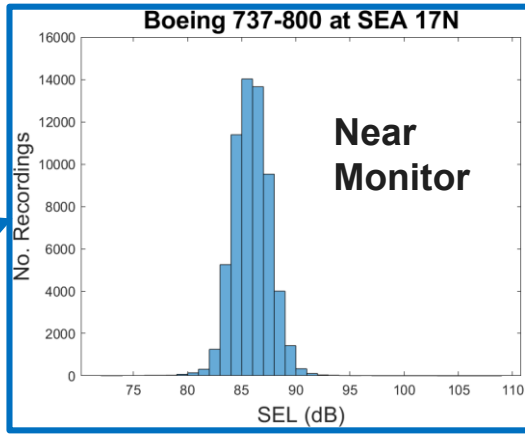
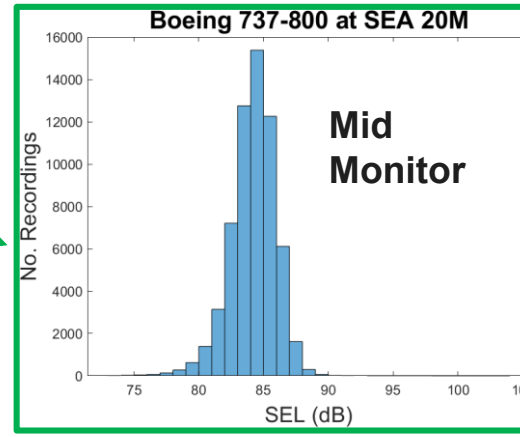
Introduction

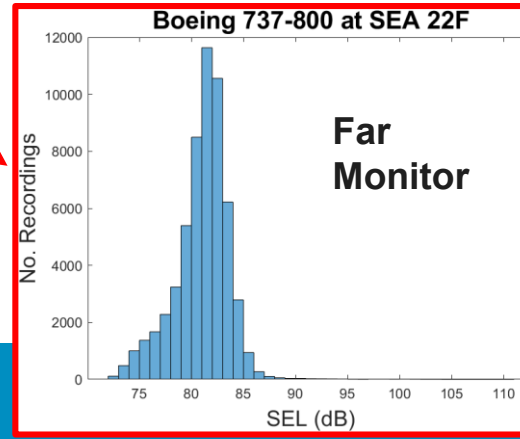
- Significant variation in measured overflight noise has been observed for the same aircraft type flying the same arrival and departure procedures
- Using data analytics, factors contributing to variation in measured noise using publicly available surveillance data (e.g. ADS-B or Radar) may be assessed
- Understanding the cause of observed variation may give insight into causes of variation and improved noise abatement procedures



737-880 departures Seattle-Tacoma International Airport (SEA)



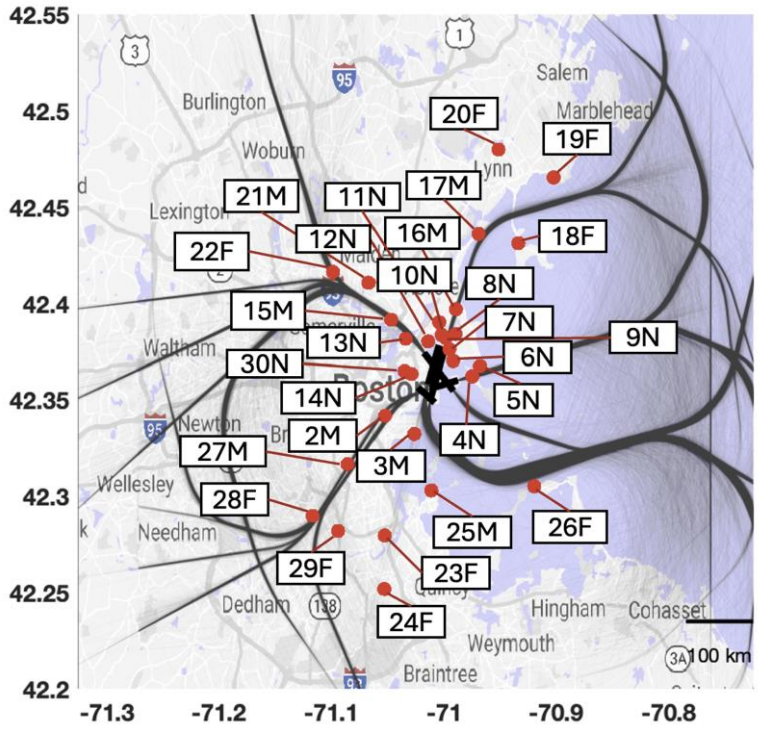




ASCENT 044 Objective

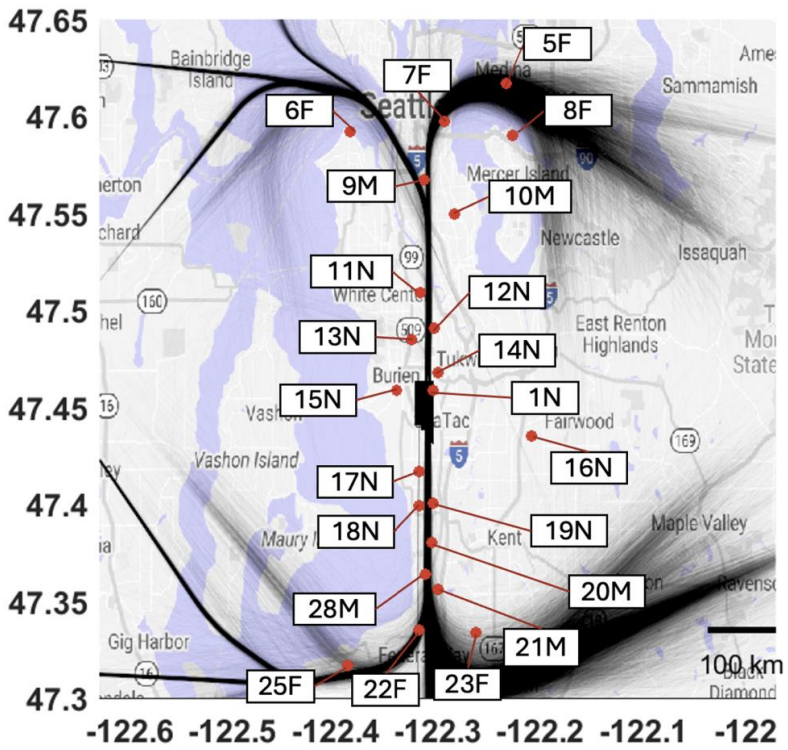
To utilize empirical noise data to develop data-based/learned noise models for validation and improvement of existing noise models and advanced operational flight procedure design.

Focus Airport Noise Monitors & Flight Data



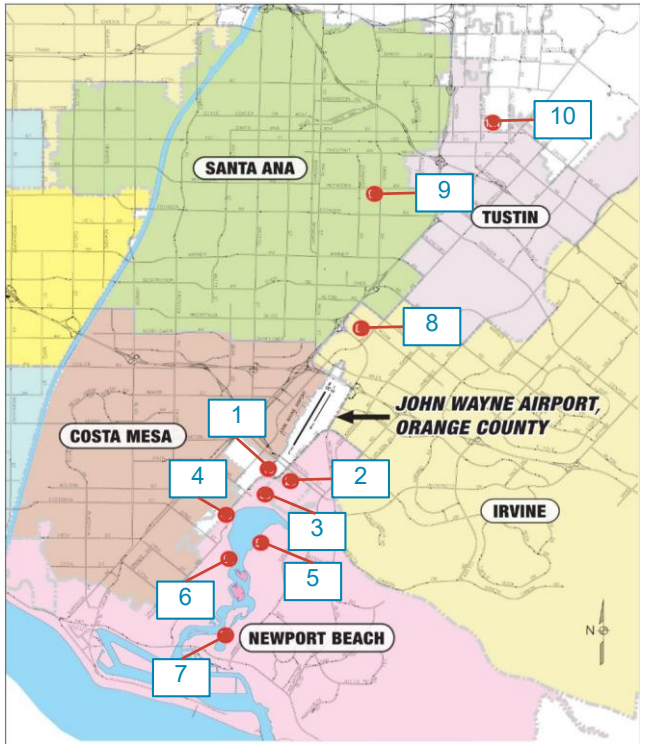
BOS

Sep 2022 – Aug 2024
(2 years)



SEA

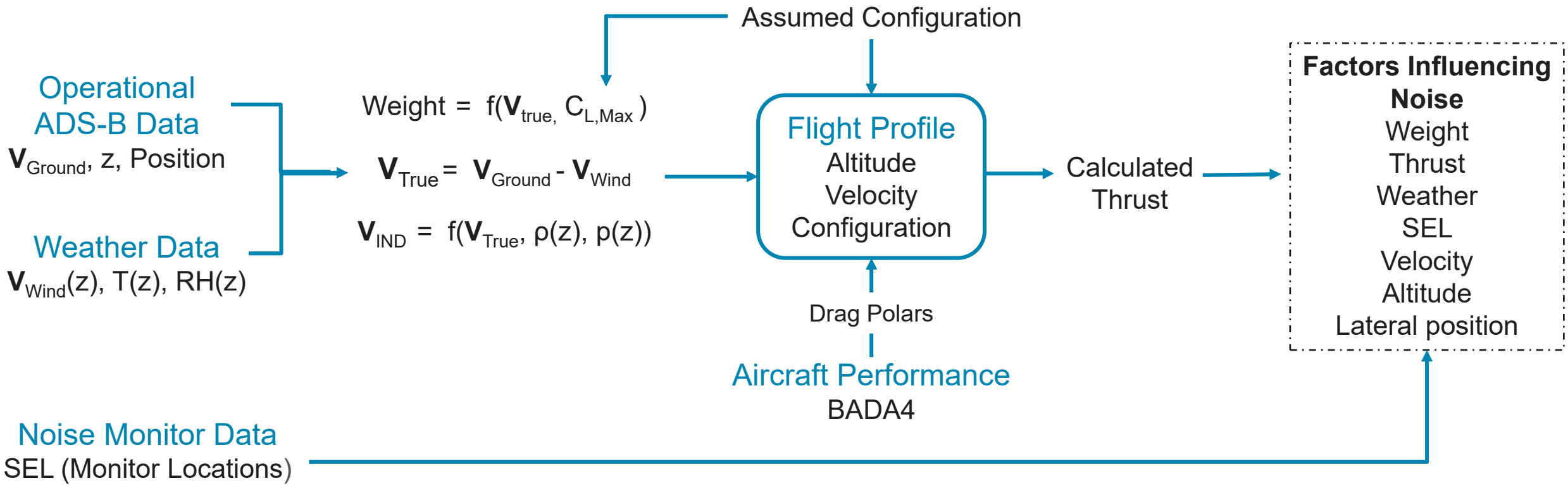
Nov 2021- Sep 2024
(3 years)



SNA

Jan 2022 – Dec 2024
(3 years)

Framework for Associating Operational, Weather and Noise Data to Derive Factors Influencing Overflight Noise



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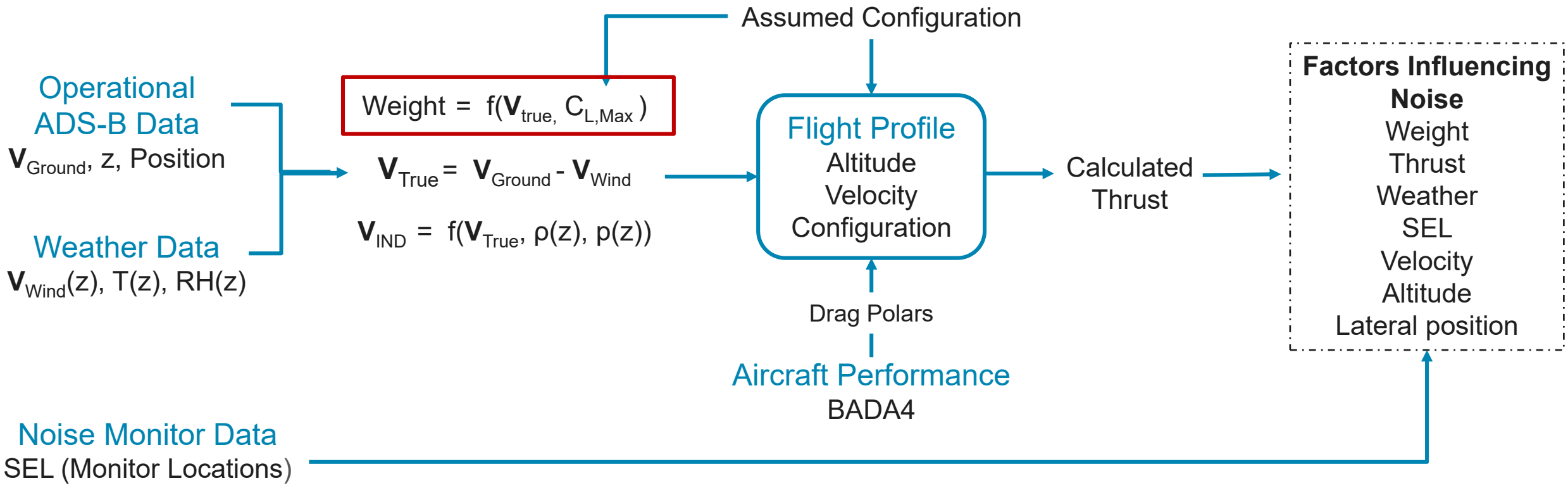


- Noise due to operational flights requires estimating take-off and landing weight
- Weight data is proprietary → Weight estimation method needed

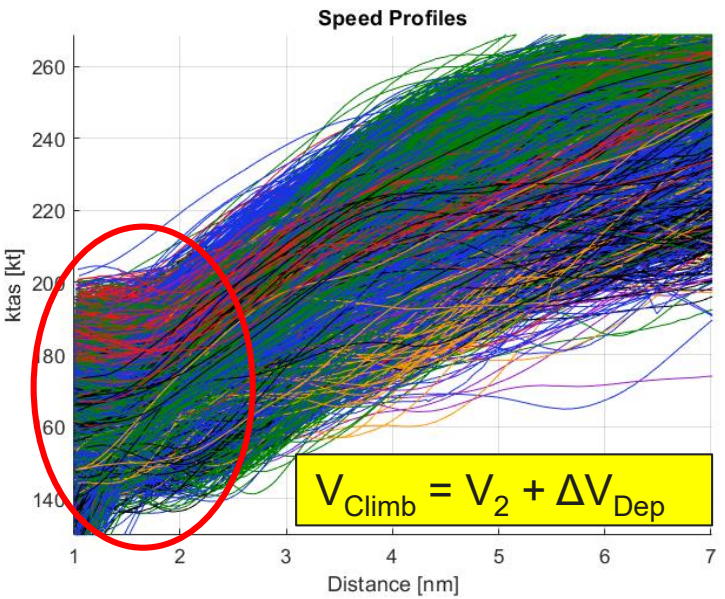
Speed Based Weight Estimation

- **Standard Procedure Basis:**
  - Standard procedure is for most airlines and airports is to fly target initial climb speeds and final approach speeds which are based on aircraft weight.
  - Speeds are observable in ADS-B data
  - Weight can be estimated

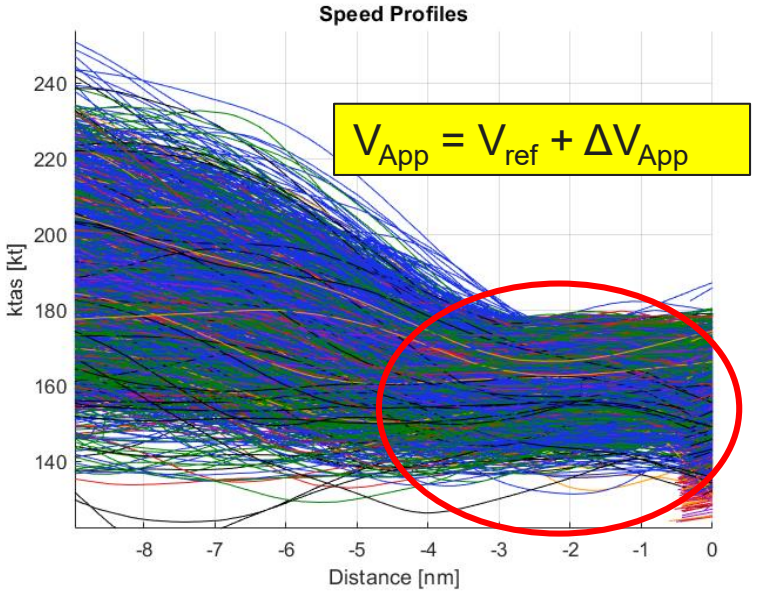
- **Takeoff Initial Climb Speed Assumption**
  - V_{climb} - V_2 (weight, flap) + ΔV
  - V_2 = 1.2 V_{stall}(weight, flap)

- **Landing Final Approach Speed Assumption**
  - V_{app} - V_{ref} (weight, flap) + ΔV
  - V_{ref} = 1.23 V_{stall}(weight, flap)

- **Calibration**
  - ΔV and flap values were calibrated with data from collaborating airline



Departures

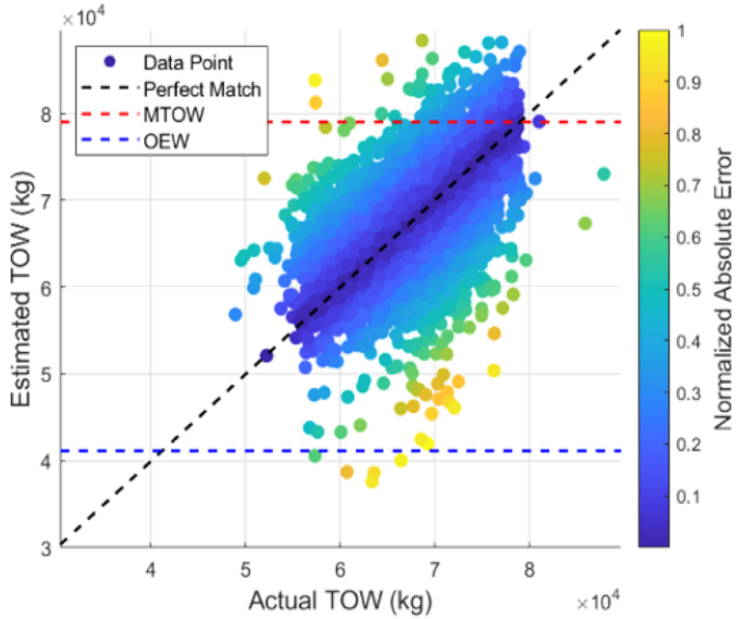


Approaches

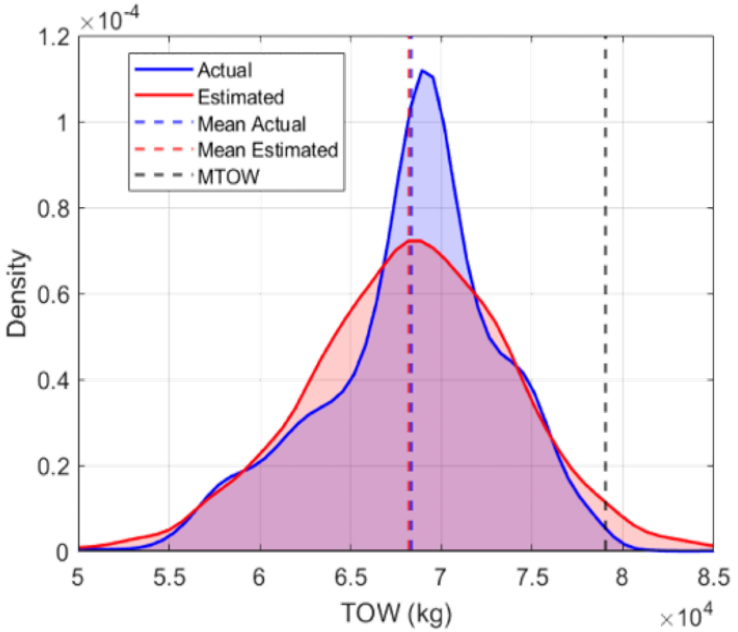
Weight Estimation: Example Results

B738 Departures

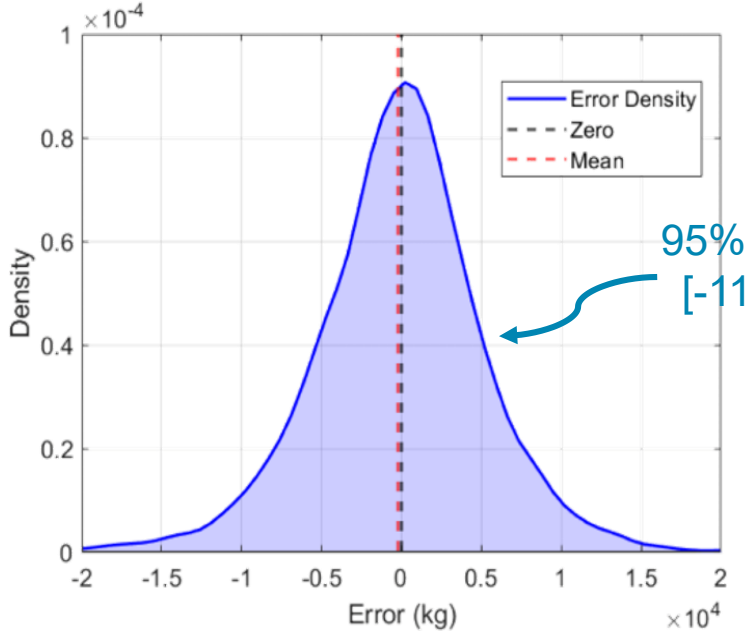
Scatter: Estimated vs Actual W



Estimated vs Actual W Distribution



Error Distribution

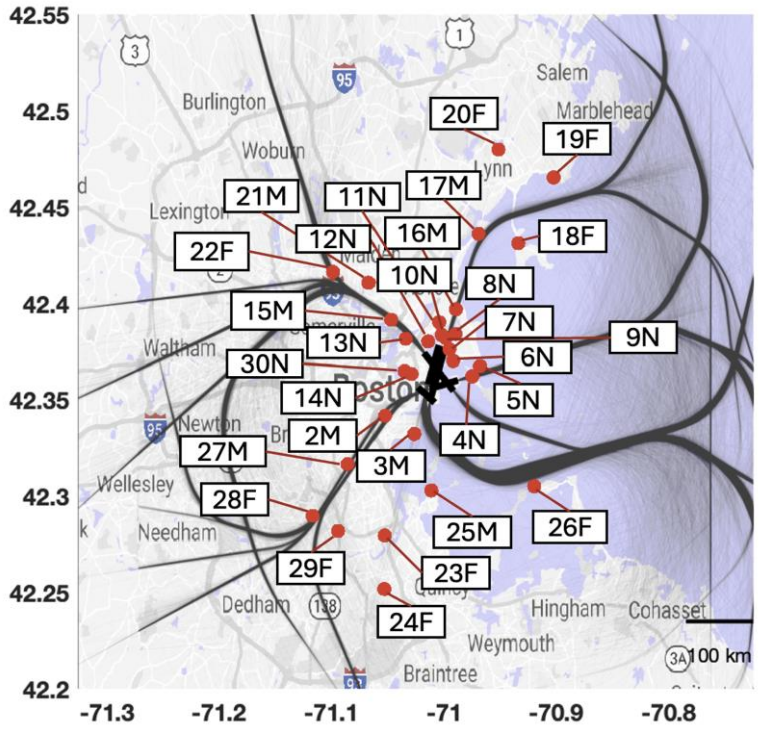


95% of Error in [-11, 11] tons

*In process of validating the method for departures and arrivals at BOS and SNA

Paper:
Take-Off and Landing Weight Estimation
From ADS-B Airspeed Profiles

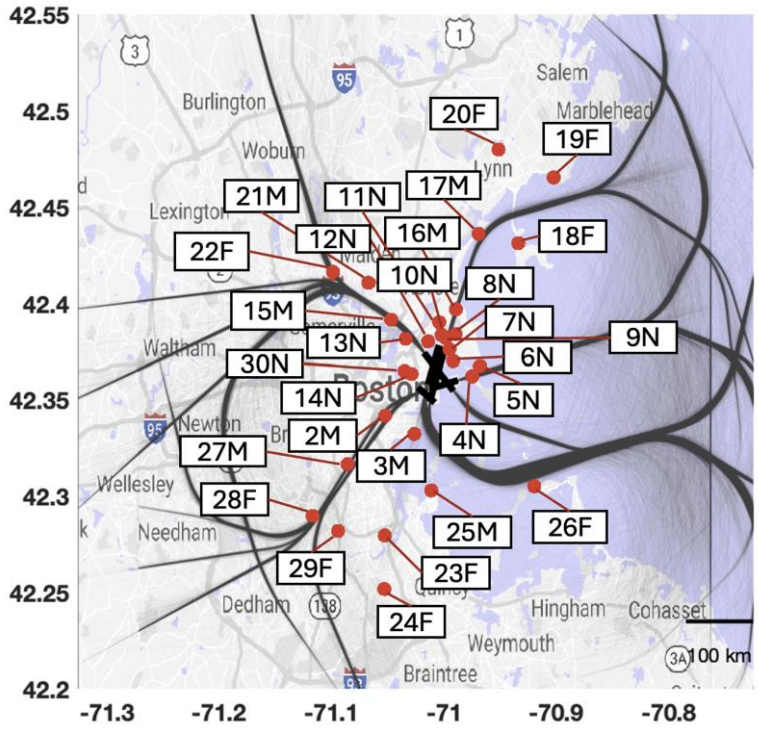
Validation of A23 RNAV Procedures at BOS



BOS

Sep 2022 – Aug 2024
(2 years)

Validation of A23 RNAV Procedures at BOS



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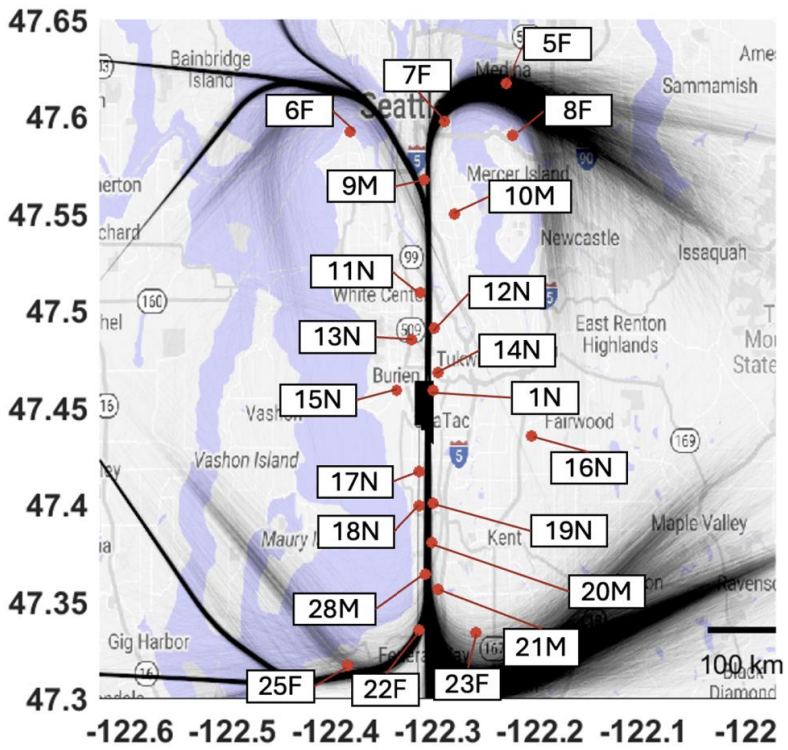

SEA

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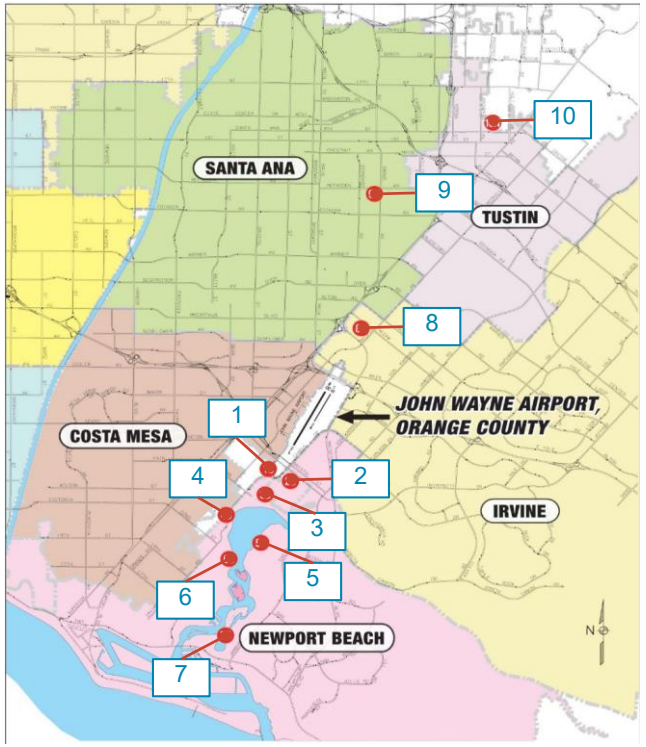
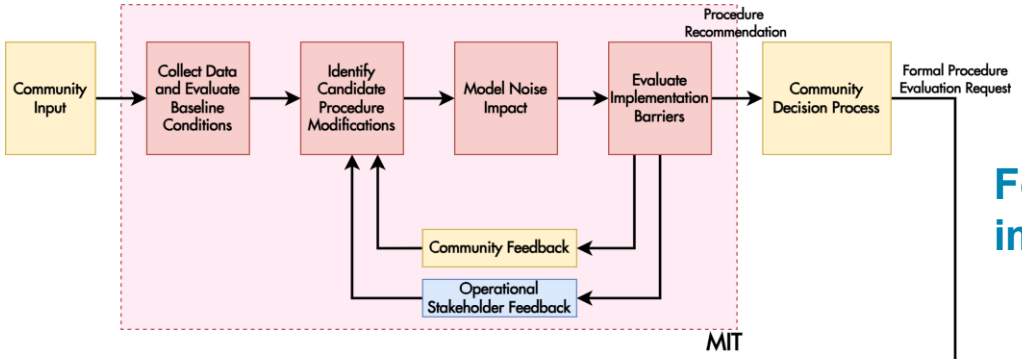


SNA

Jan 2022 – Dec 2024
(3 years)

Validation of A23 RNAV Procedures at BOS



Four procedures (two departures and two arrivals) were selected for implementation based on population impact and community feedback:

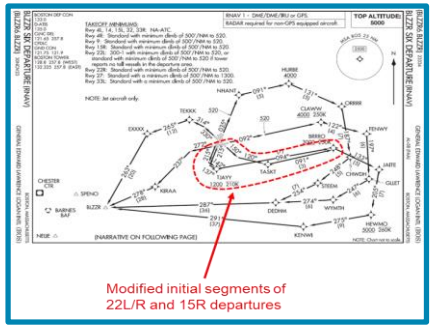
12/2/21
15R Departure published

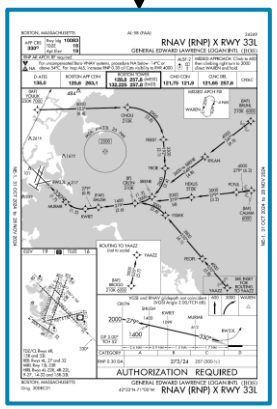
12/30/21
33L Arrival published

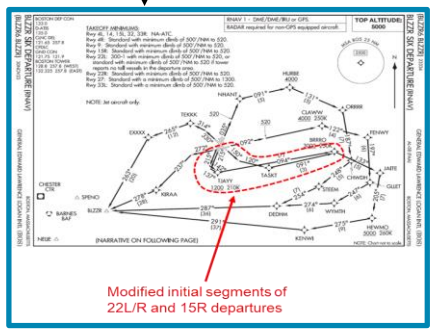
11/30/23
22L/R Departure published

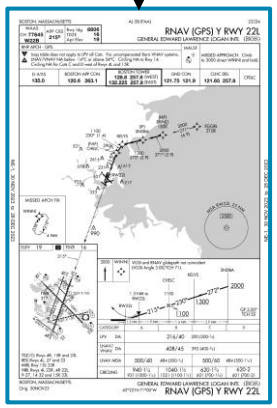
07/08/25
22L Arrival operational

Post-implementation analyses





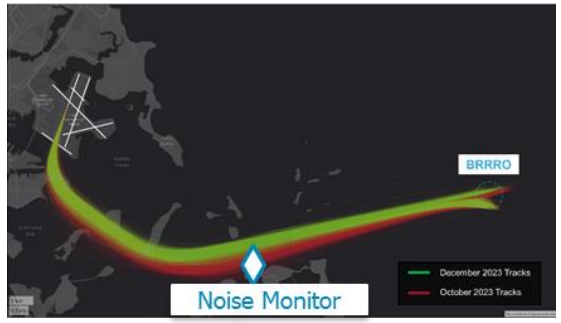


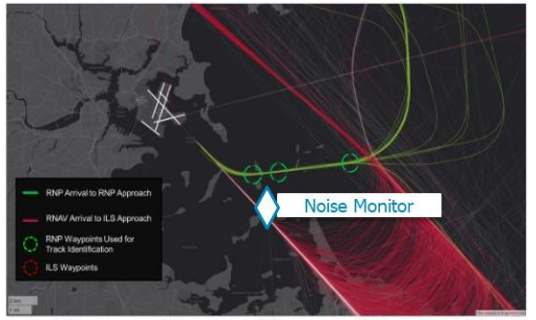


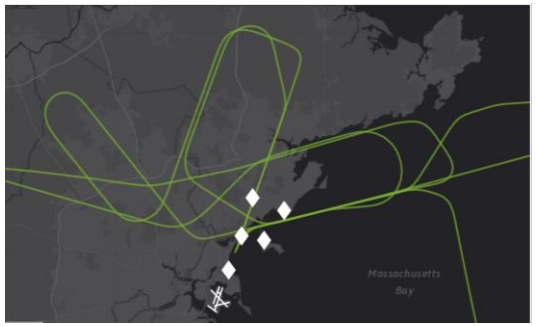
Low-Noise RANV Procedures at BOS
Post-Implementation Analysis Results

Quantifiable benefits using flight trajectory data and raw noise signal from the noise monitor indicated with ◊ :

Flight Tracks

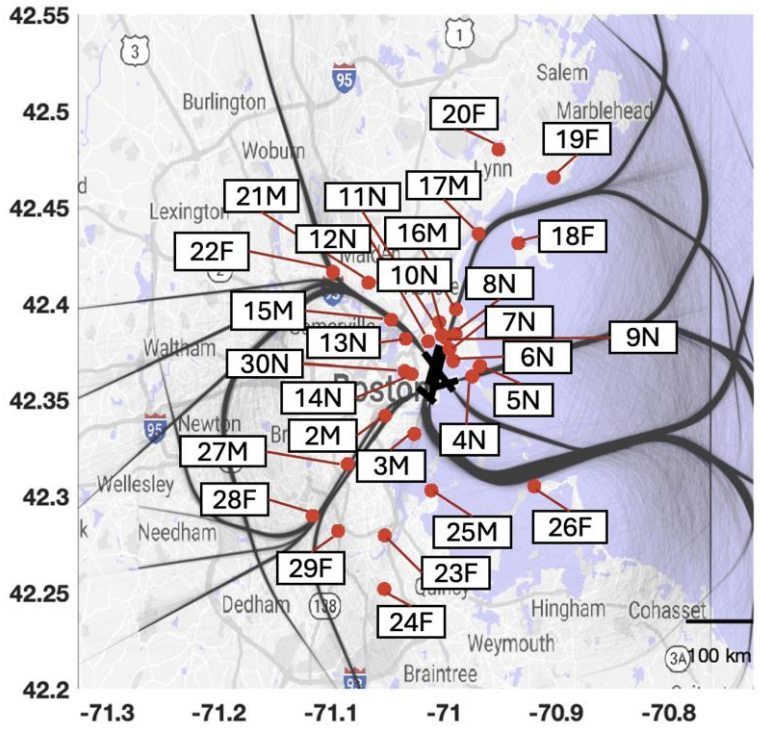






Procedure	15R Departure	22R Departure	33L Arrival	22L Arrival
Noise Impact	4.5 dB reduction	2.9 dB reduction	18.3 dB reduction	Recently Operational Analysis in progress
Distance Impact	0.2 NM saved	0.1 NM saved	7.4 NM saved (northwest) 2.3 NM saved (southwest)	

Focus Airport Noise Monitors & Flight Data



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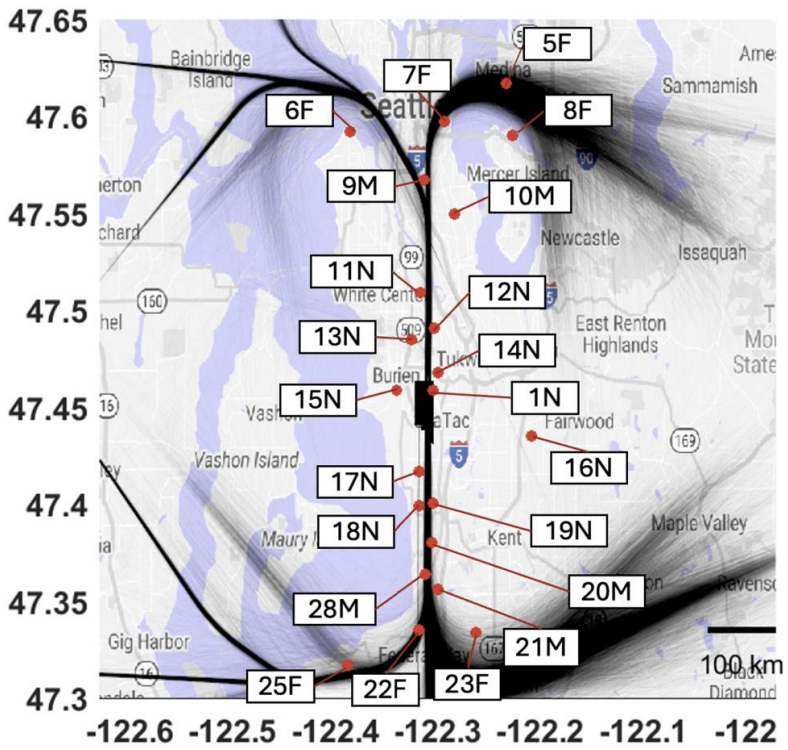

SEA

Nov 2021- Sep 2024
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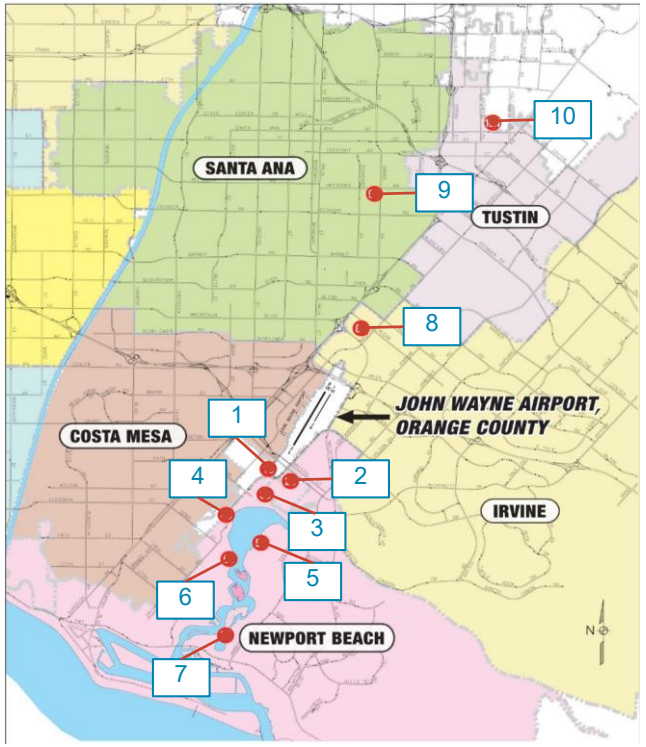


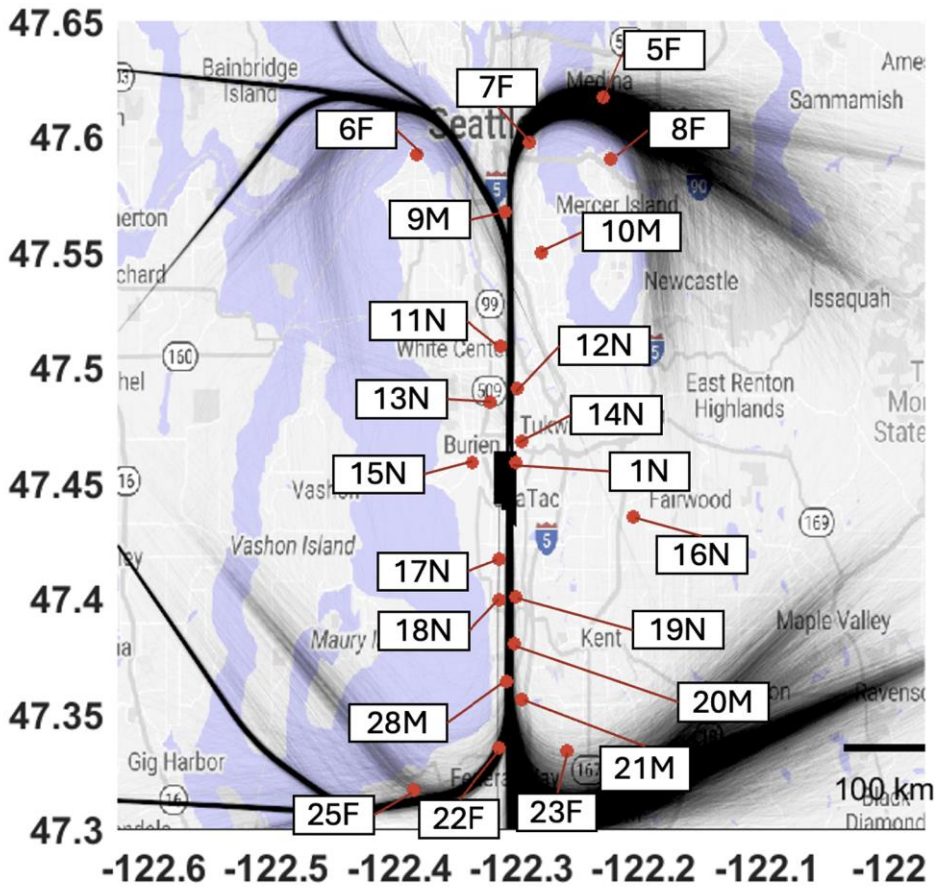
SNA

Jan 2022 – Dec 2024
(3 years)

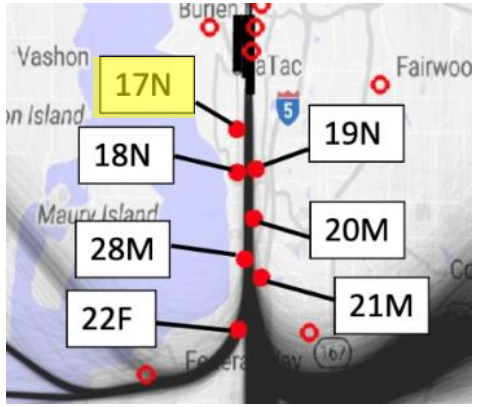
Individual Monitor Analysis Approaches Evaluated

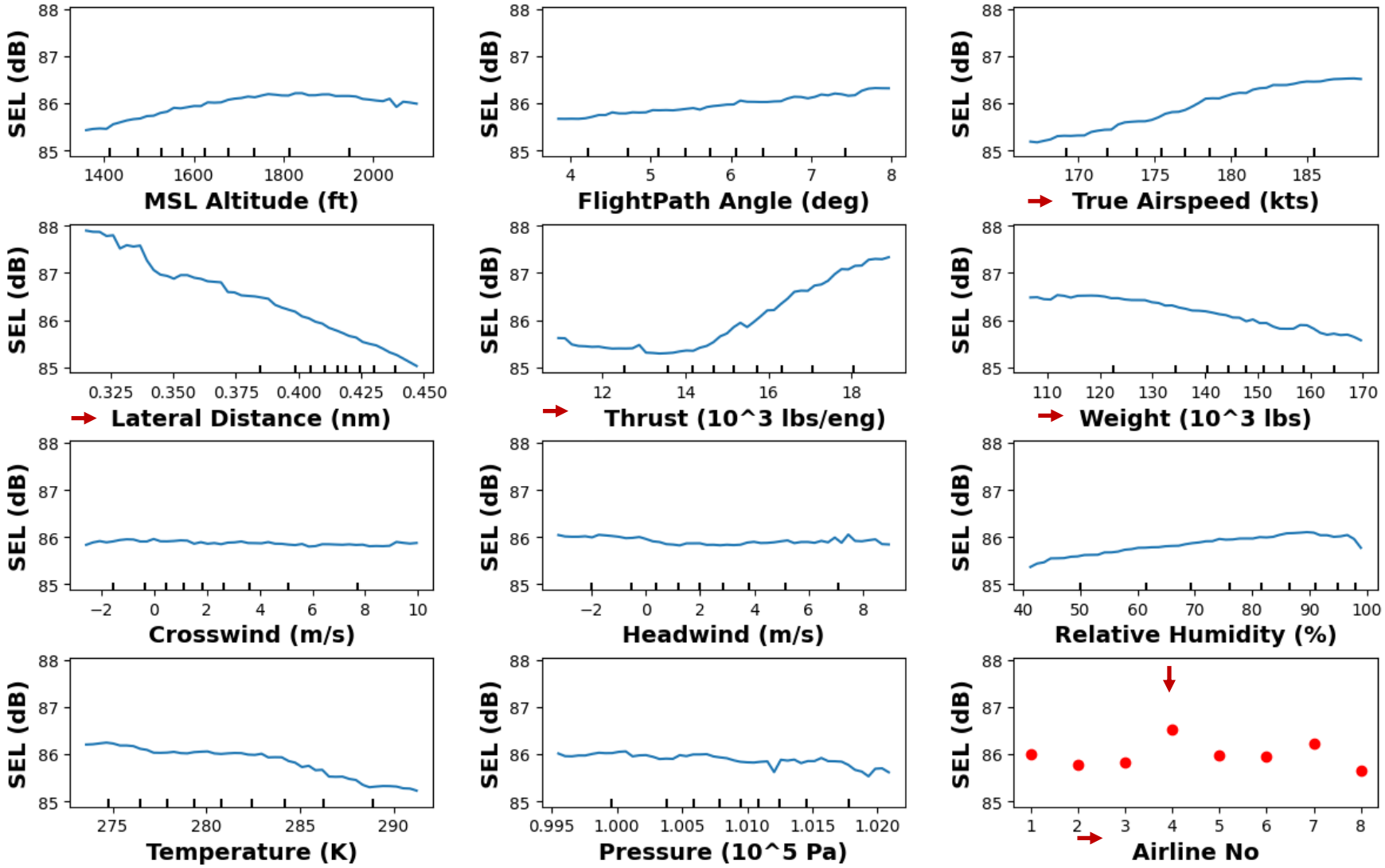
- Regression Based Approaches
  - Linear
  - Multivariate
- Hierarchical Clustering
- Gradient Boosted Regression Trees
- Partial Dependance Plots

- Trends Constant with expected instantaneous factors but confounded factors earlier in the flight
  - e.g. Prior Thrust >> Altitude

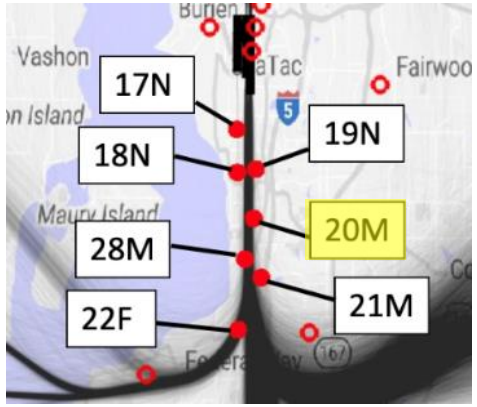


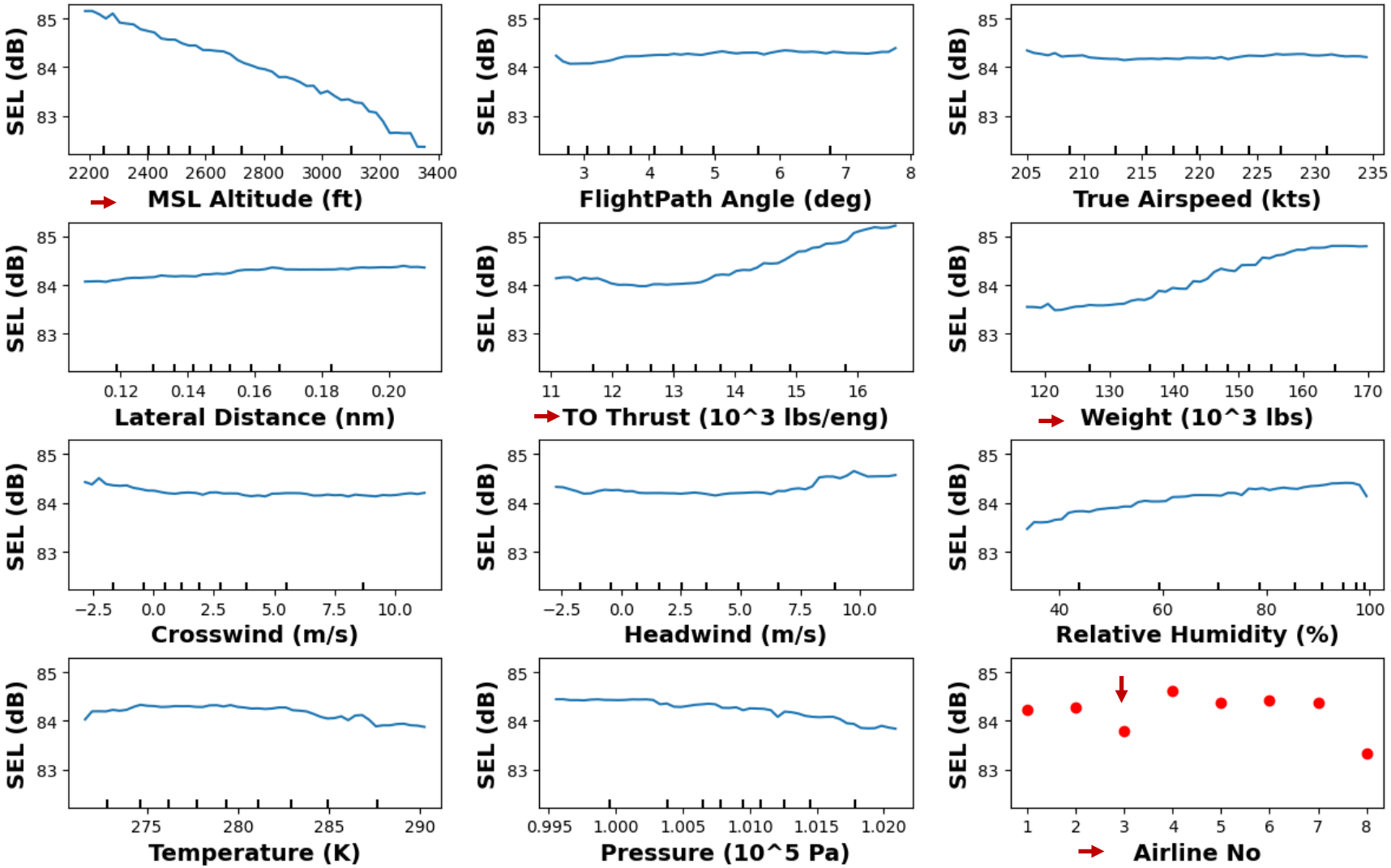
PDP: KSEA B737-800 Departures – Near Monitor



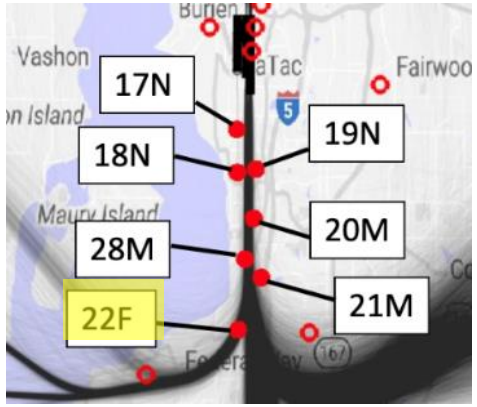


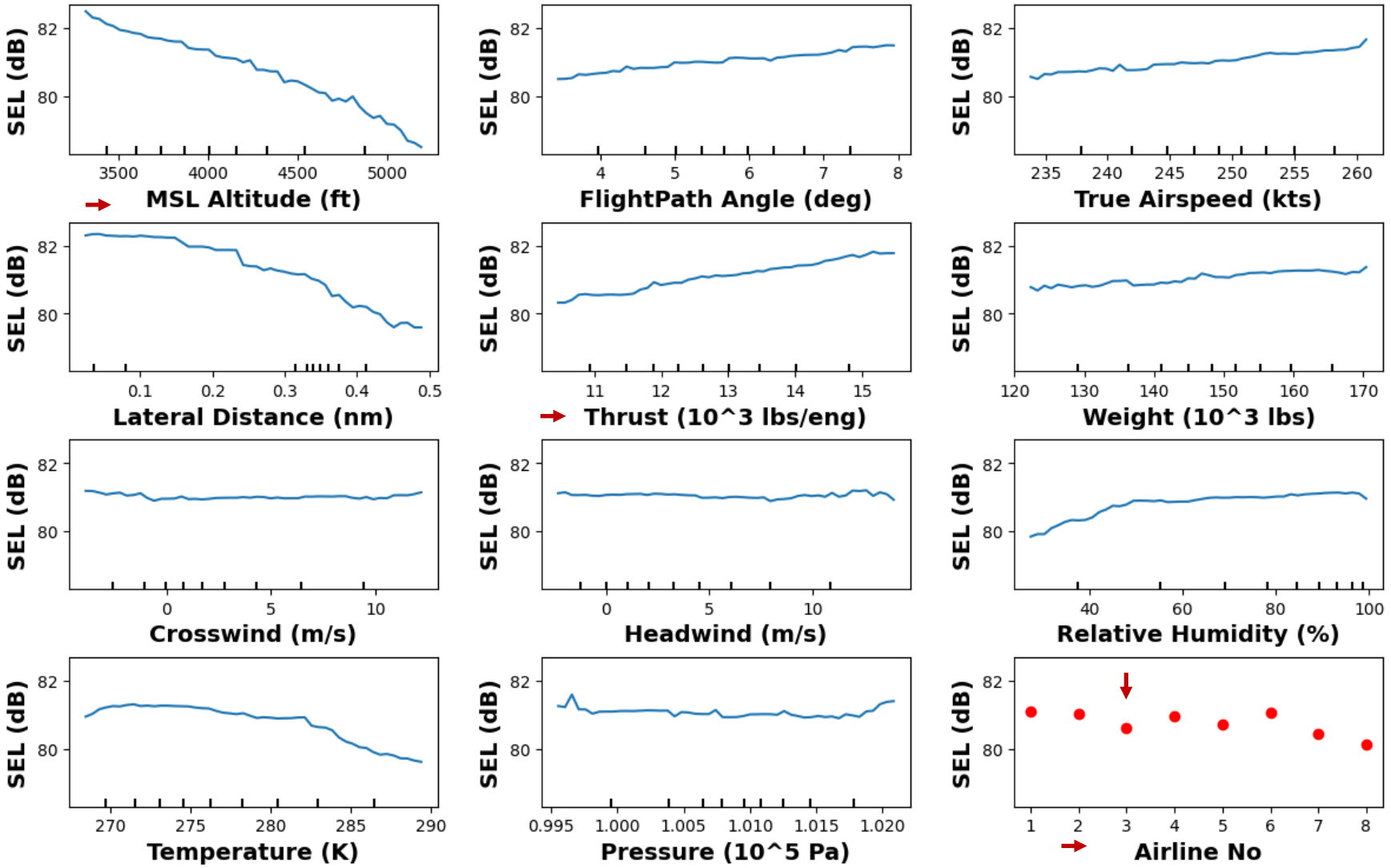
PDP: KSEA B737-800 Departures – Mid Monitor





PDP: KSEA B737-800 Departures – Far Monitor

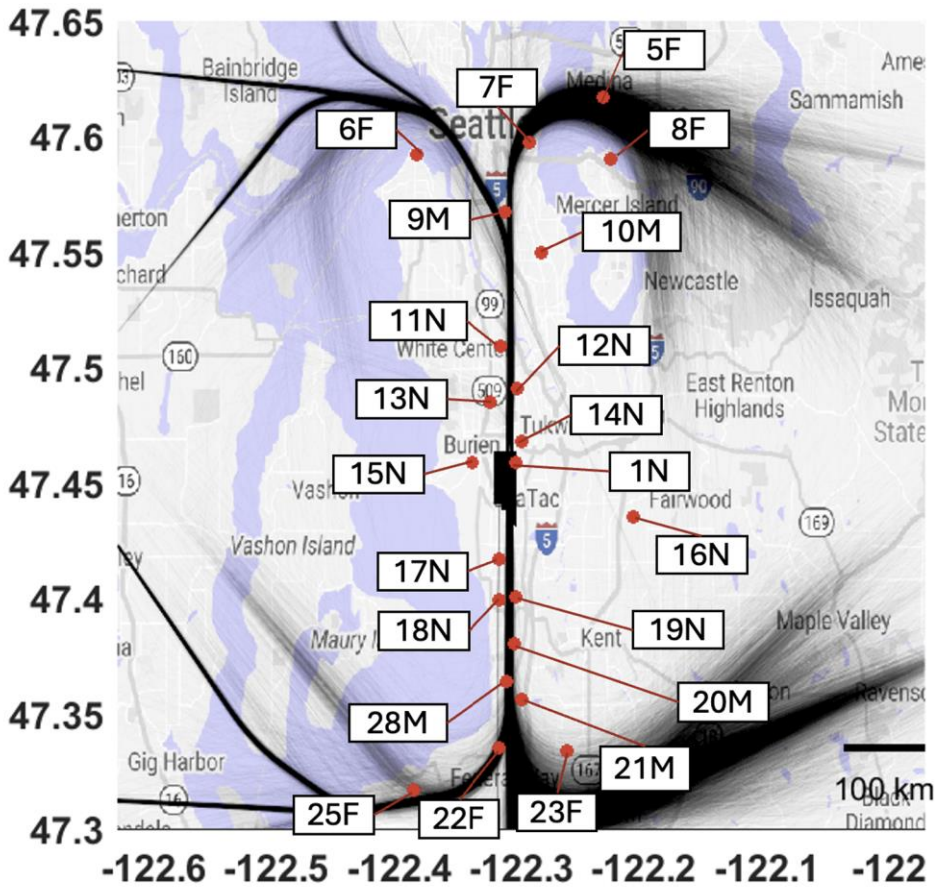




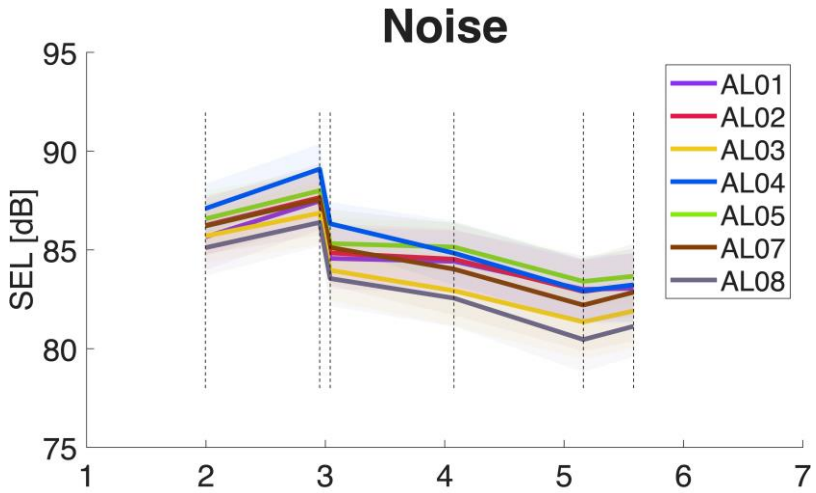
Full Procedure Based Approaches

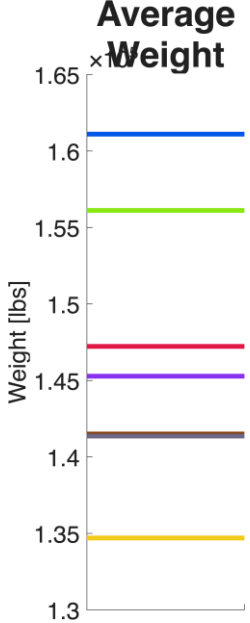
- Airline Based Grouping
  - Flight procedures standardized
  - Allows ID of procedure impacts
- Inter Airport Comparisons

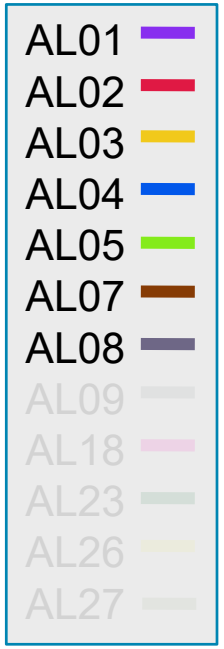
- Individual Airframe Monitoring

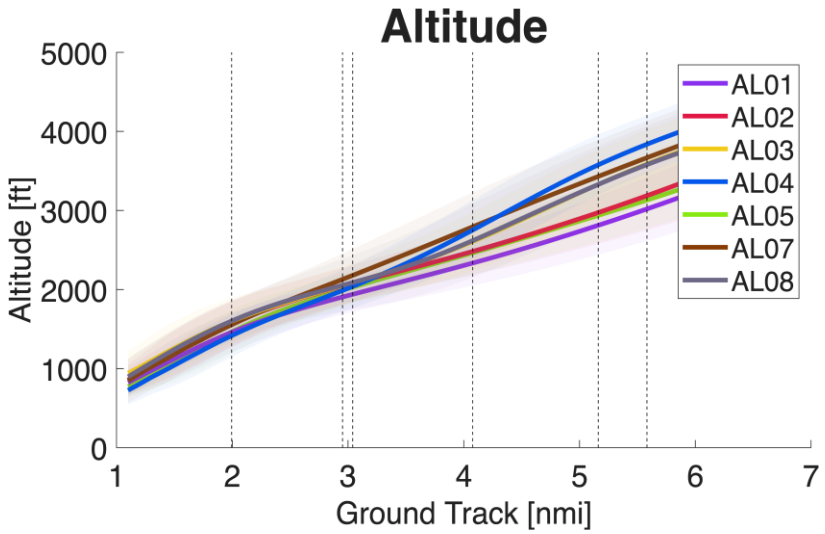


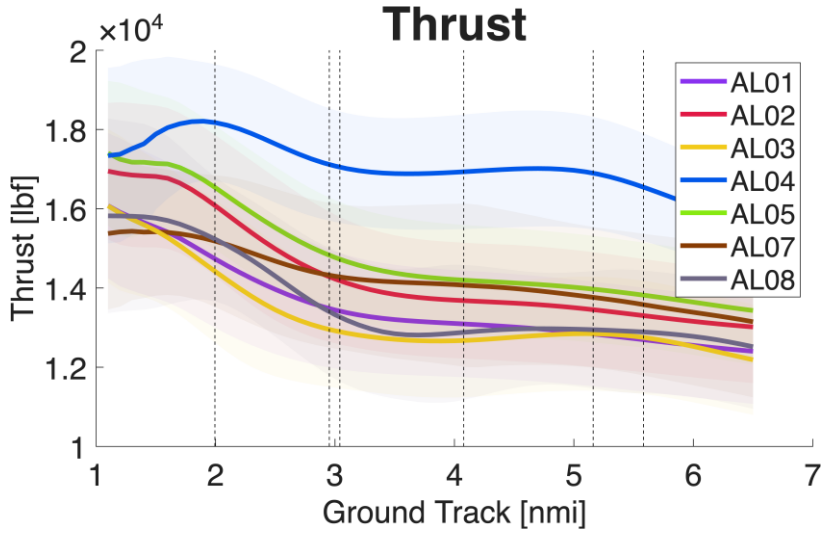
KSEA Southbound Departures
B737-800

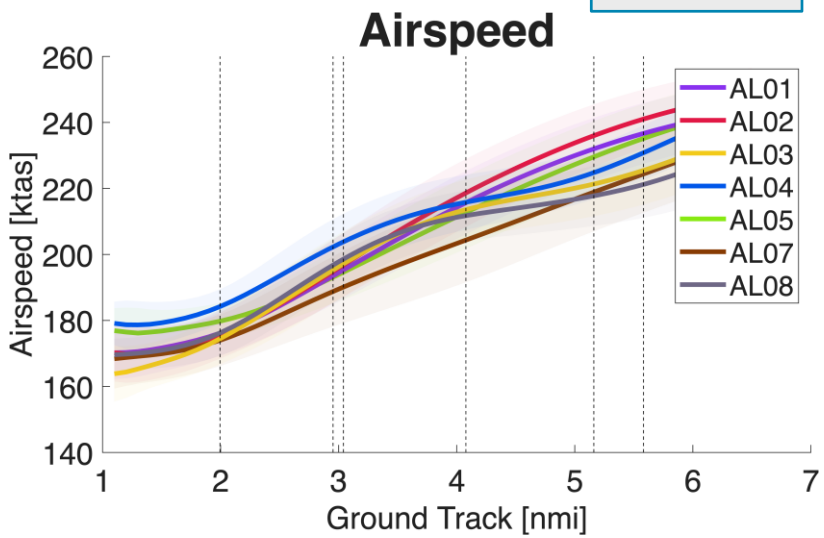






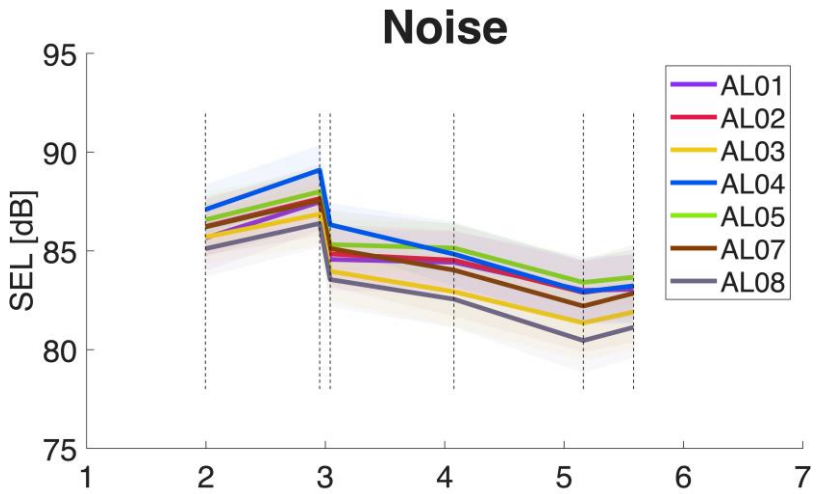


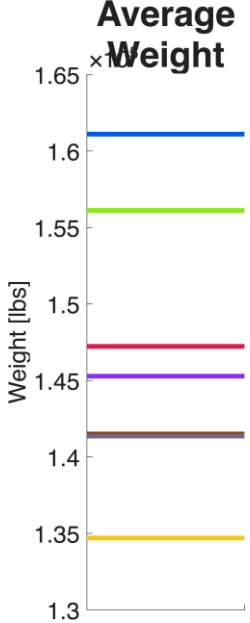


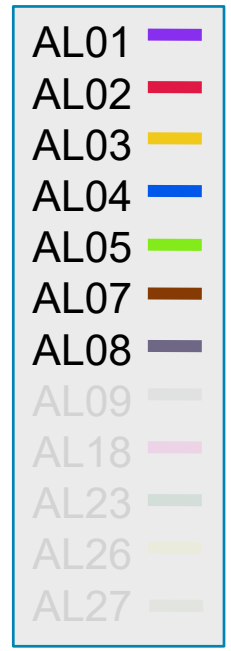


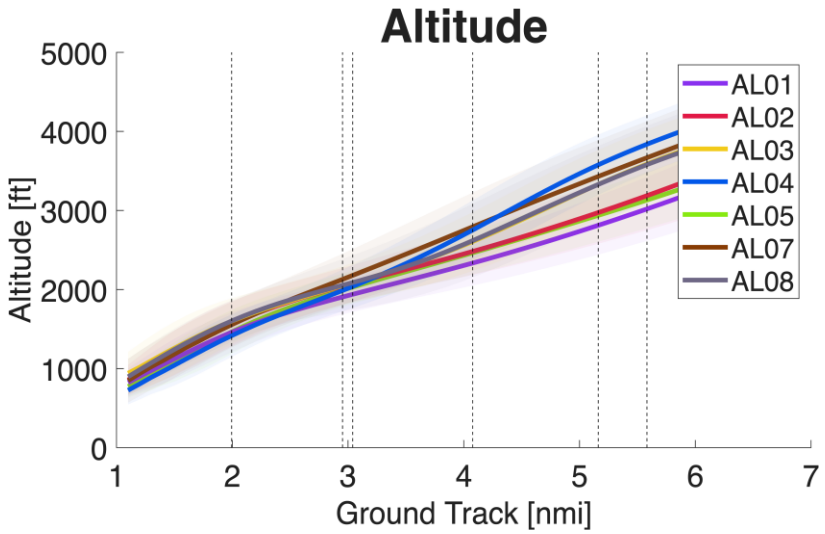
KSEA Southbound Departures B737-800

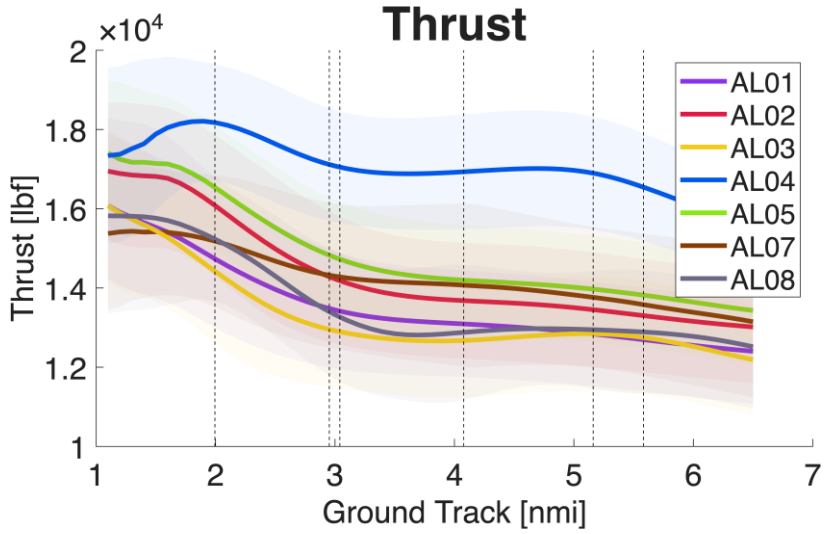
- AL4 High Weight/Thrust Initial Noise
- AL3,8 Low Weight Thrust Noise

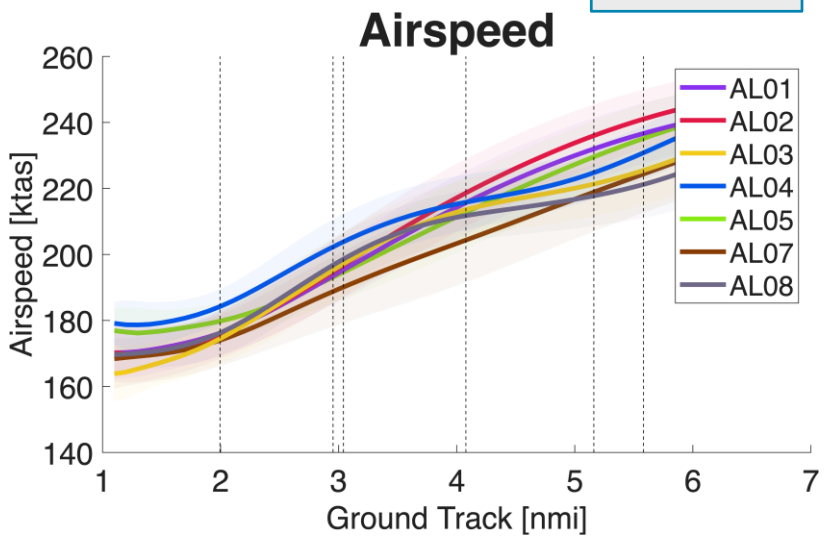






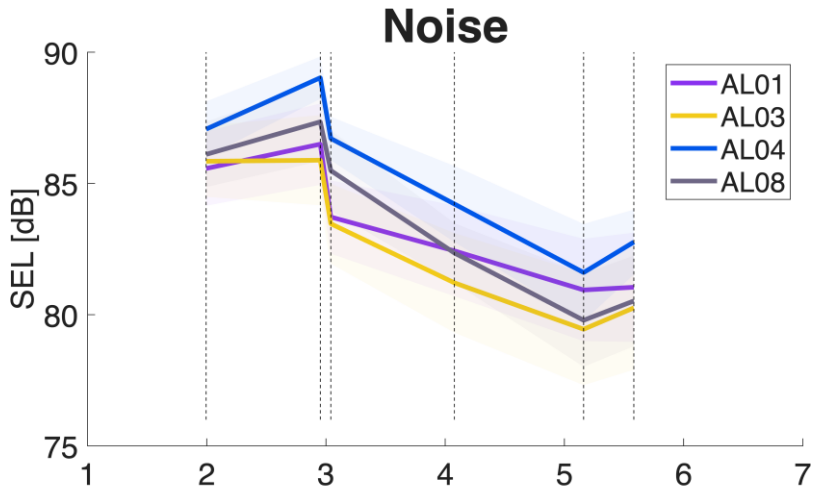


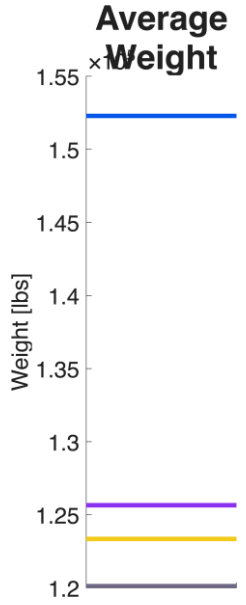


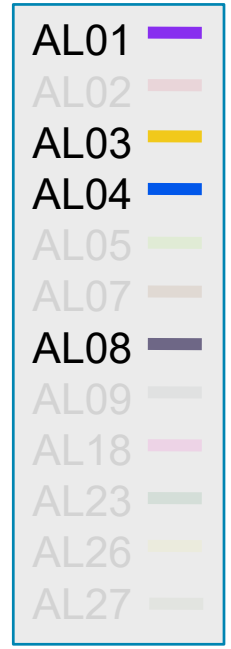


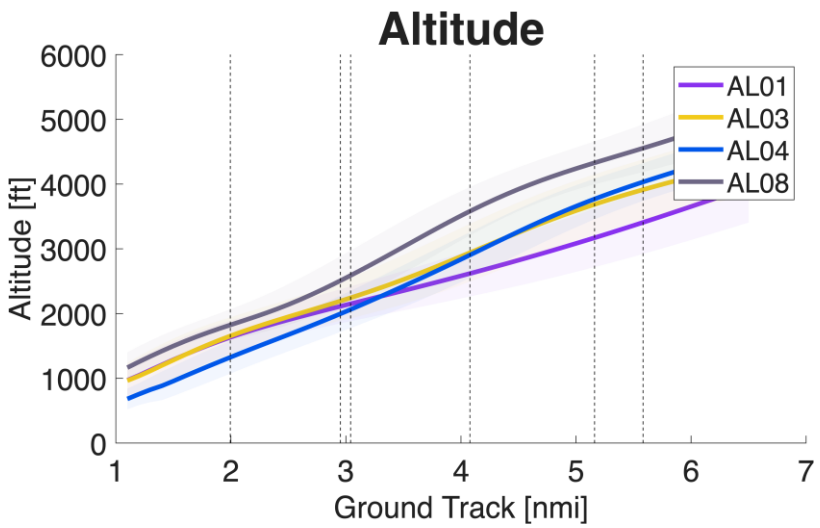
KSEA Southbound Departures B737-700

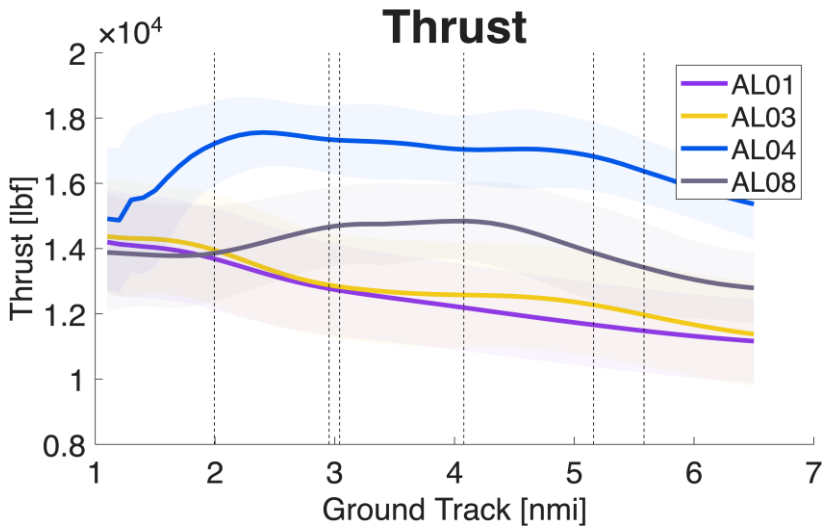
- AL4 High Weight/Thrust Noise
- AL1,8 Low Weight Thrust Noise

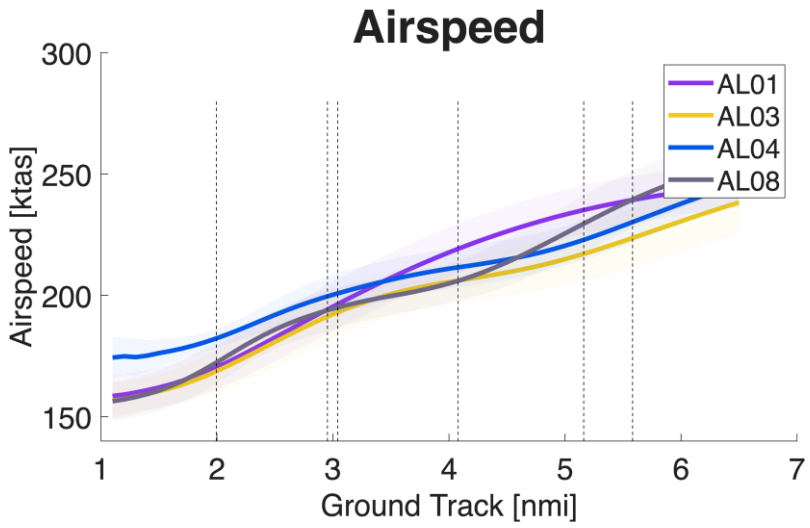






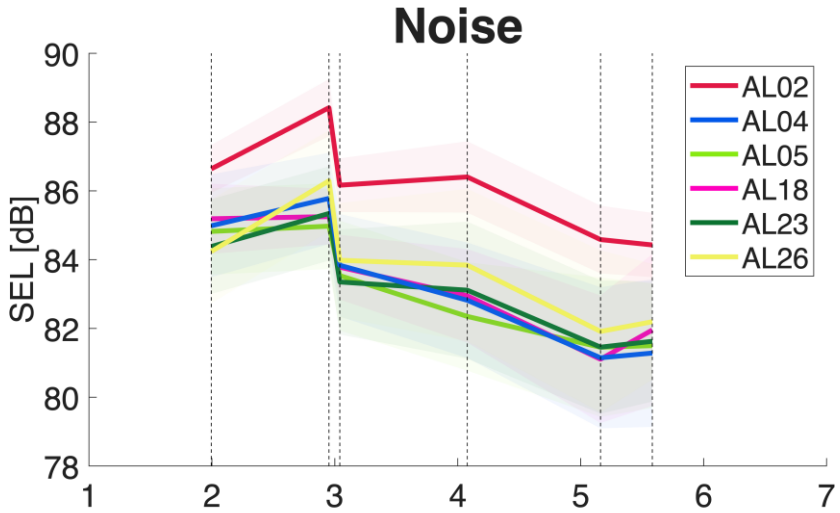


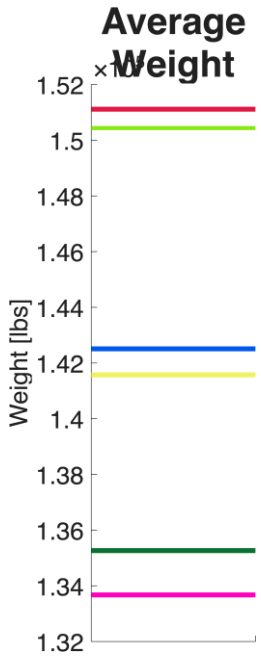


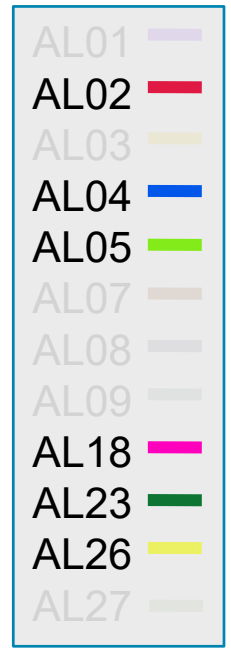


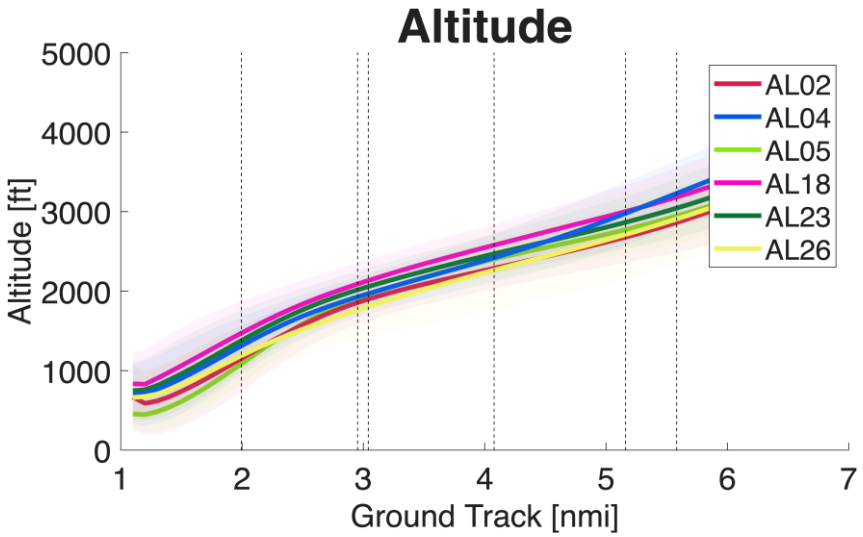
KSEA Southbound Departures A320

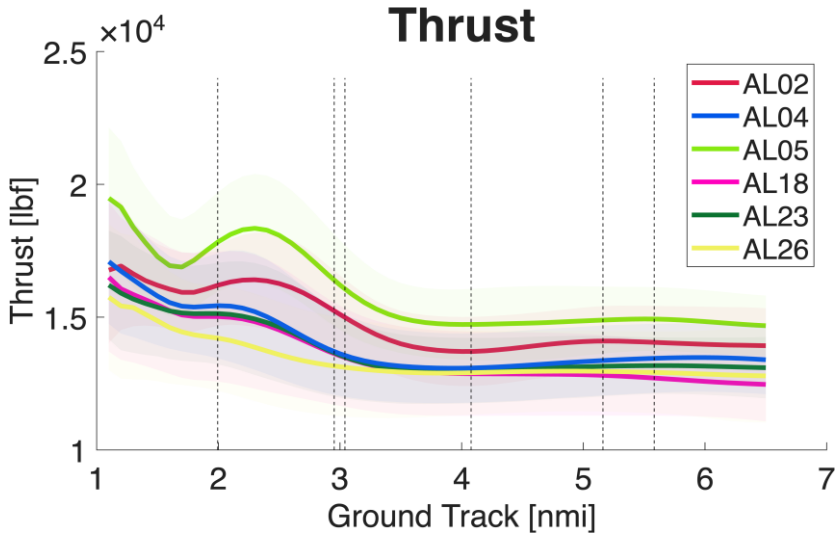
- AL2 High Weight, Low Thrust and very high noise
  - Airframe Issue
- AL5 High Thrust and weight, low noise

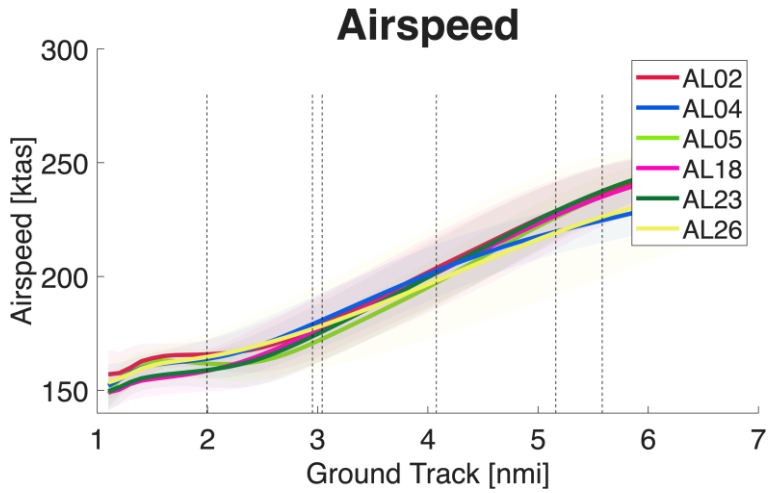






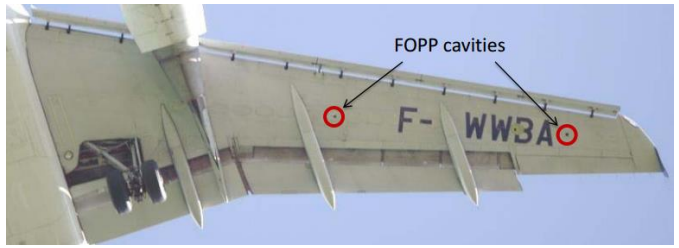




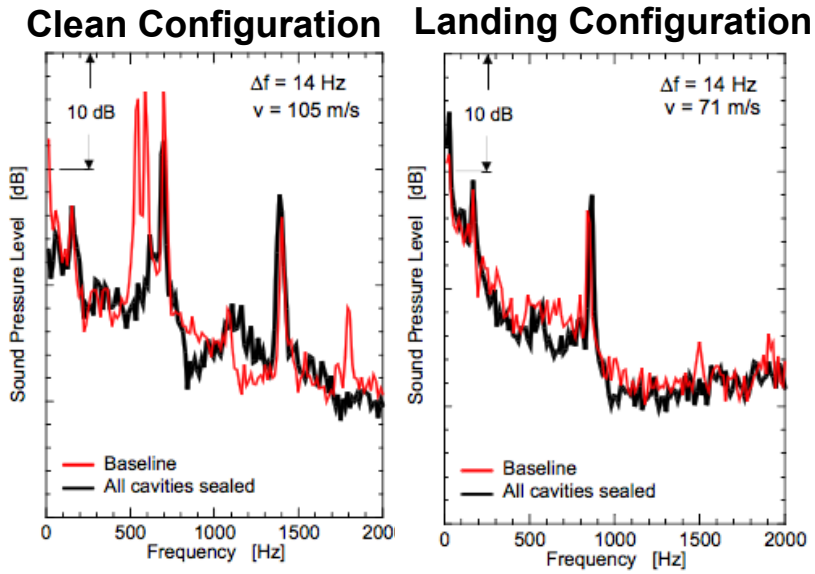


A320 Fuel Vent Noise Source

- Fuel over pressure ports (3.5” diameter) cause strong tonal noise peaks at 573 Hz
  - Perceived as a “whistling” tone louder than all other noise sources
- Tone only appears at specific speeds and aircraft configurations
  - Strongest in clean configuration



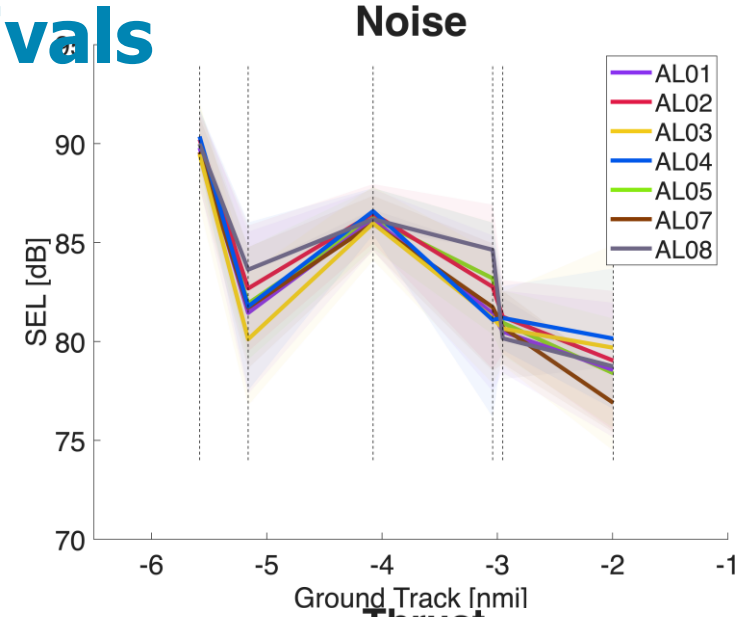
Vortex Generator Solution
Retrofit by many carriers
Installed in new aircraft

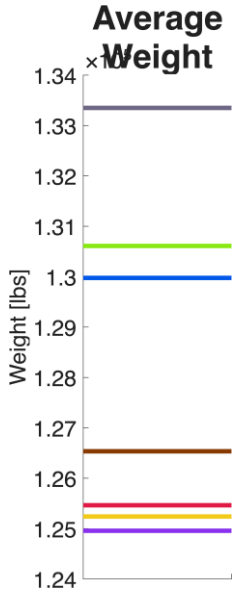


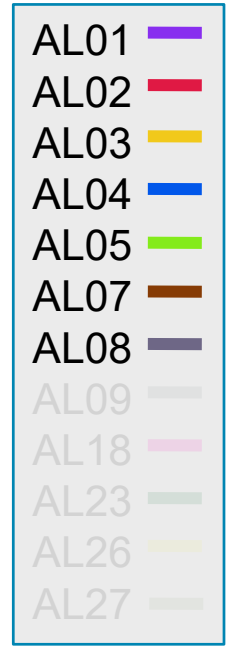
Source: "*Validation of a Semiempirical Airframe Noise Prediction Method through Dedicated A319 Flyover Noise Measurements*" by Pott-Pollenske et. al.

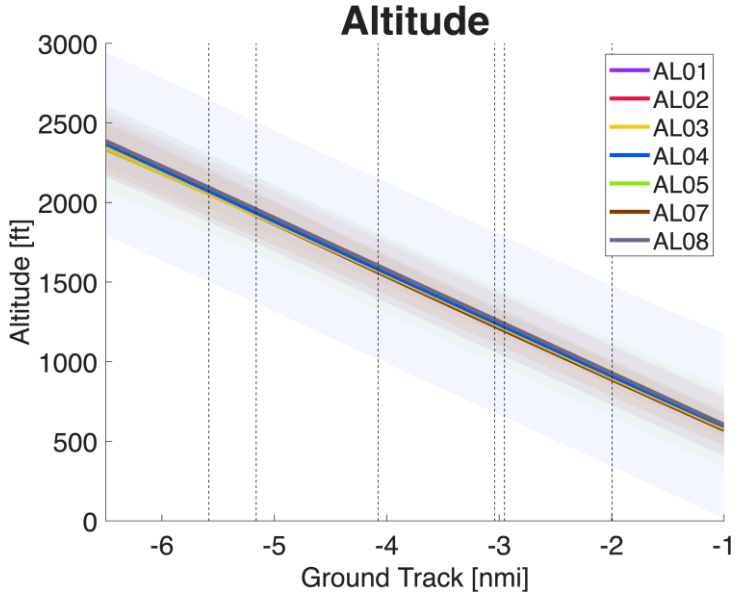
KSEA Northbound Arrivals B737-800

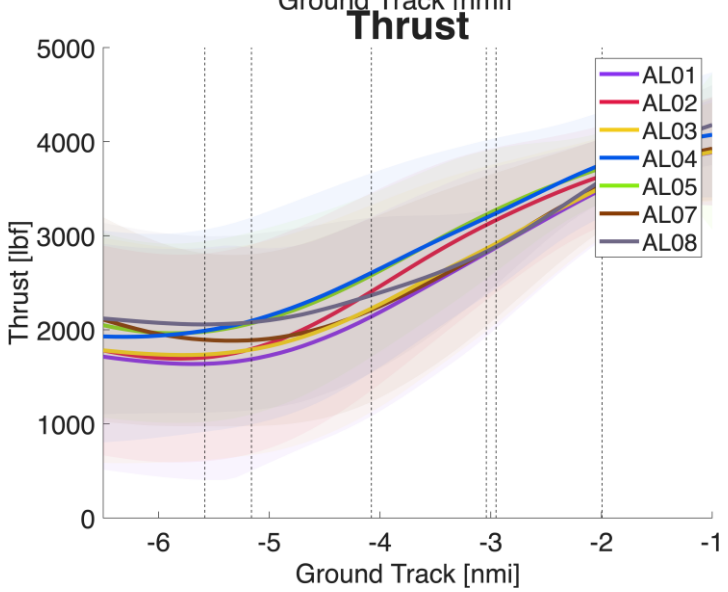
- Noise increase around 4 nm
  - Flap effect ?
- AL 8 Higher Airspeed, broader flap impact

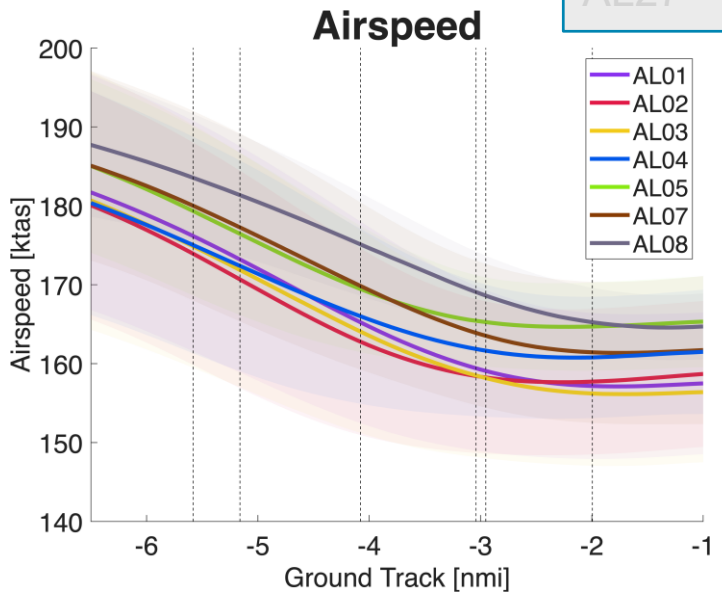






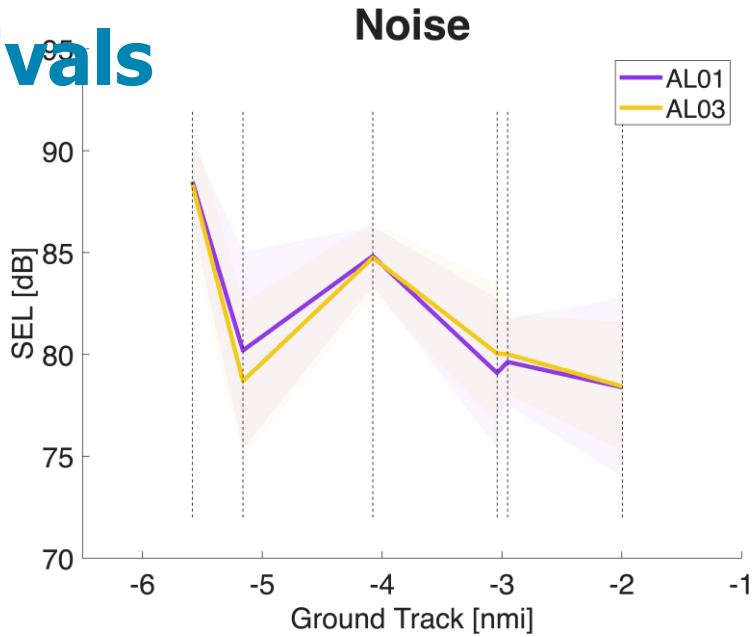


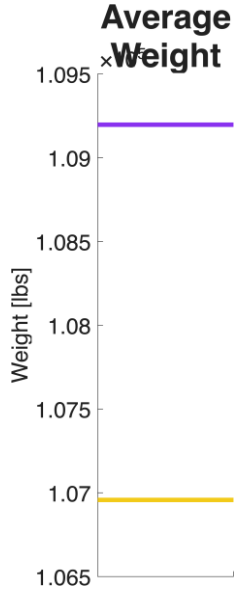


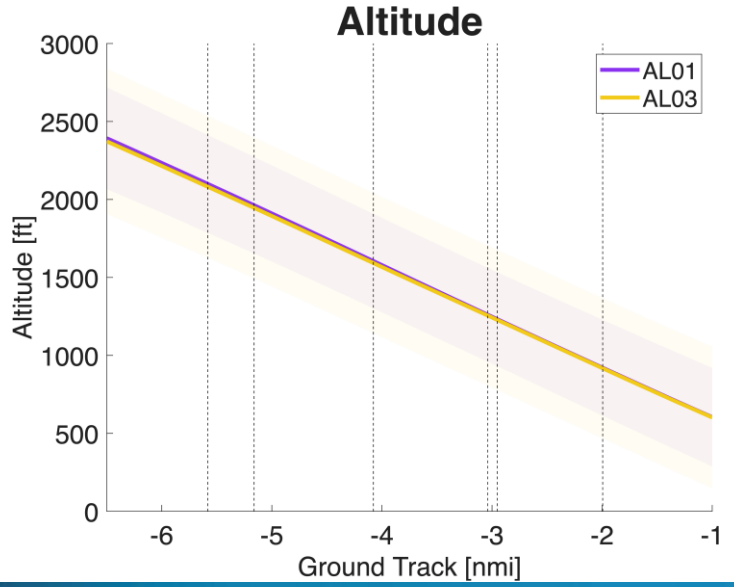


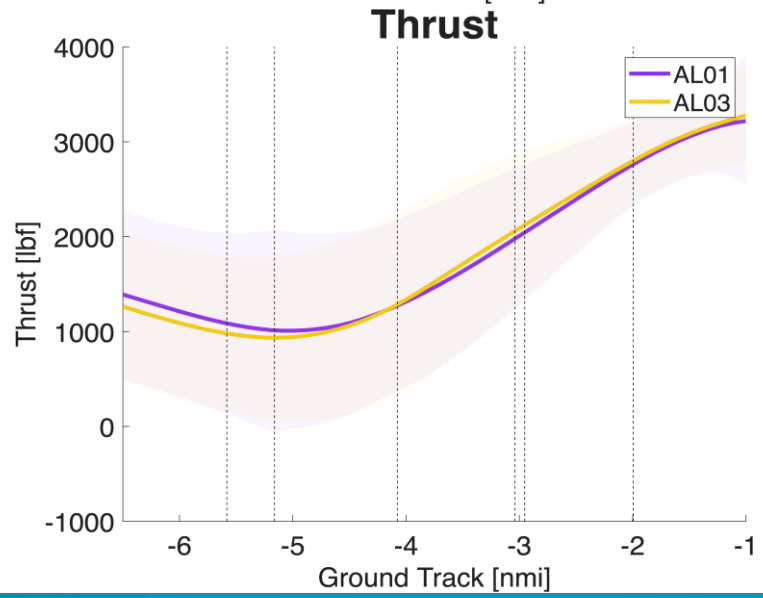
KSEA Northbound Arrivals B737-700

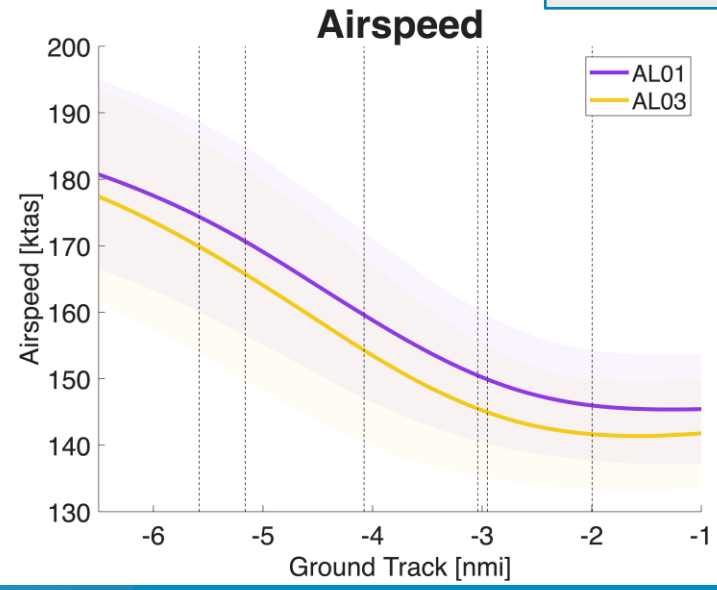
- Noise increase around 4 nm
  - Flap effect ?
  - Weak Speed impact





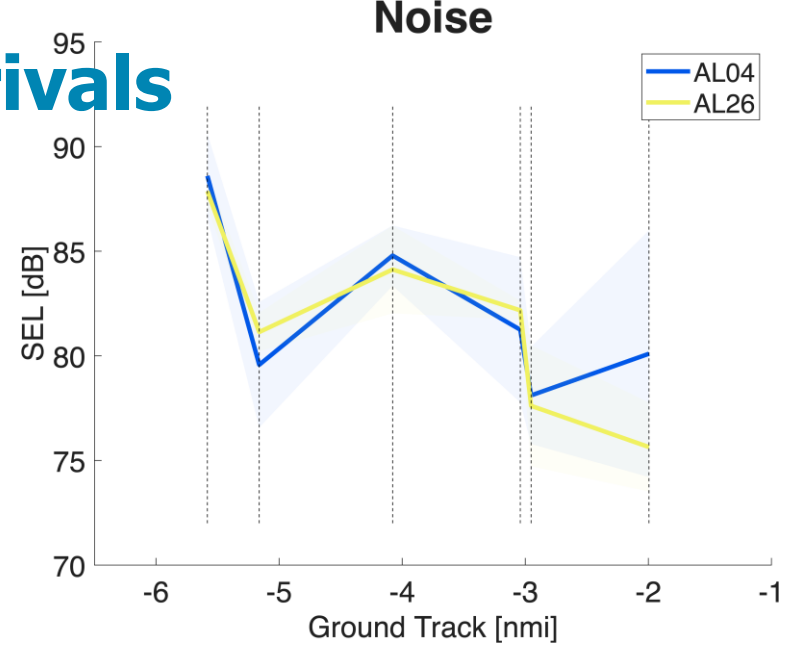


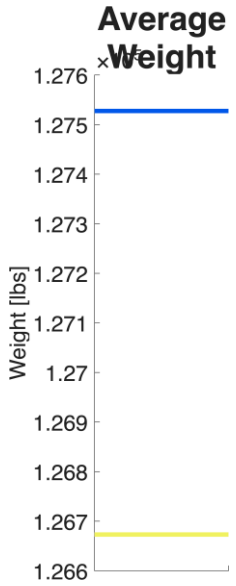


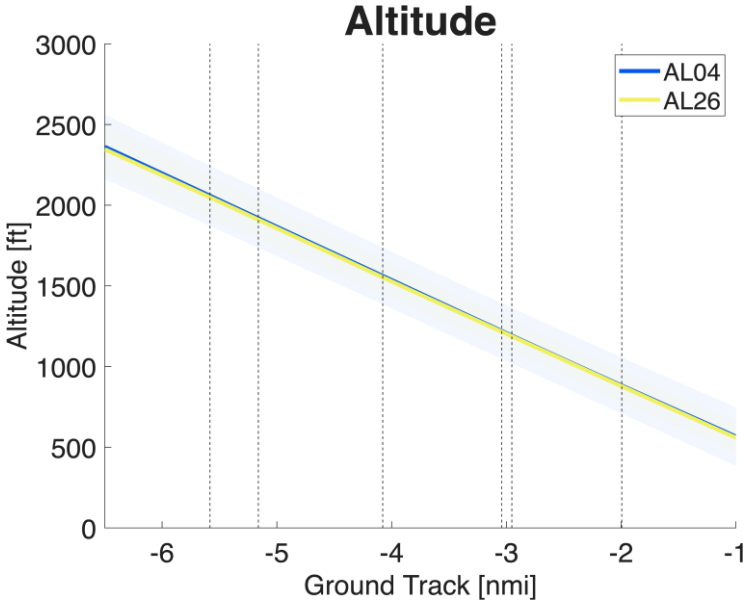


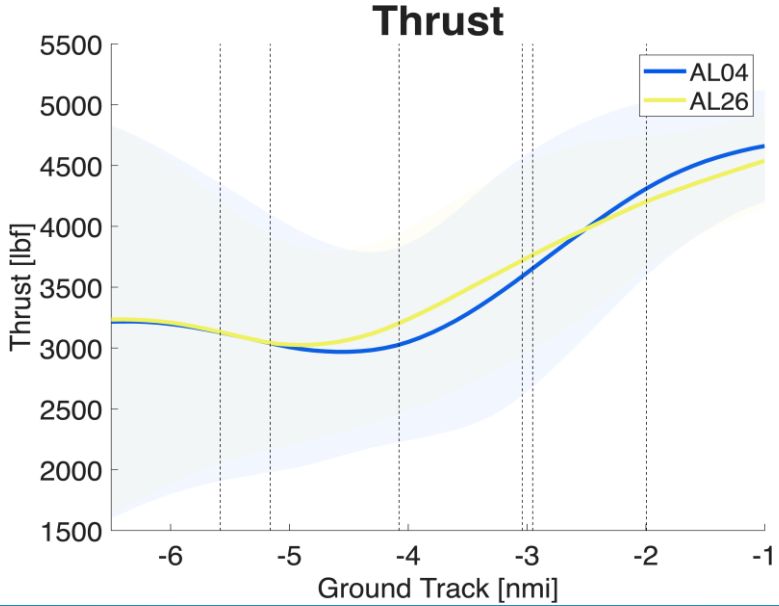
KSEA Northbound Arrivals A320

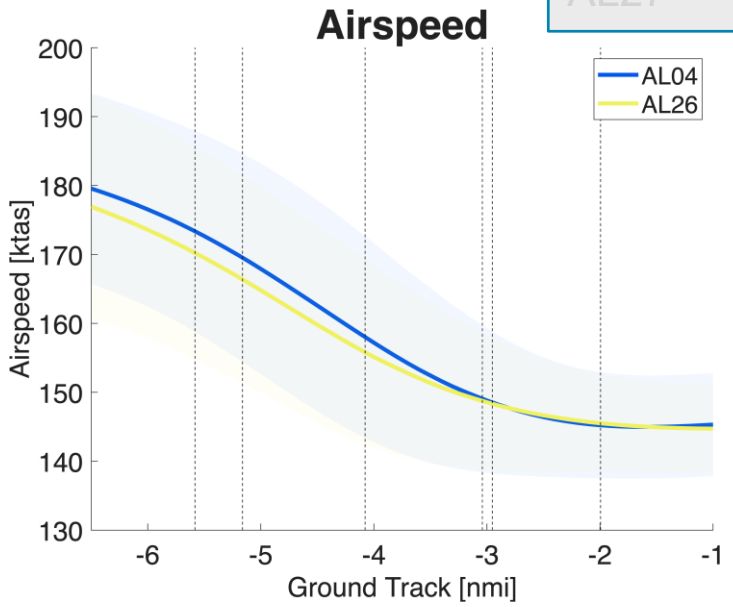
- Noise increase around 4 nm
  - Flap effect ?



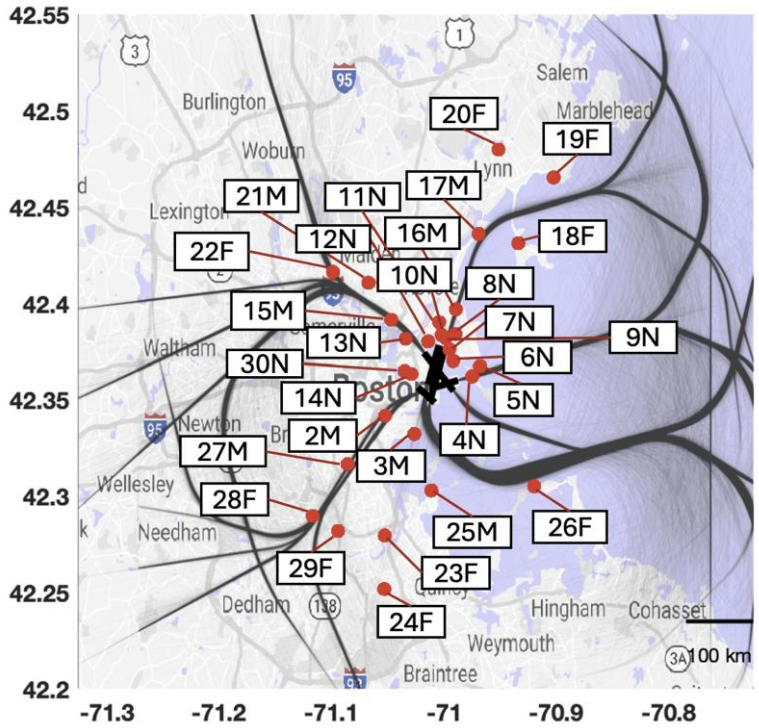






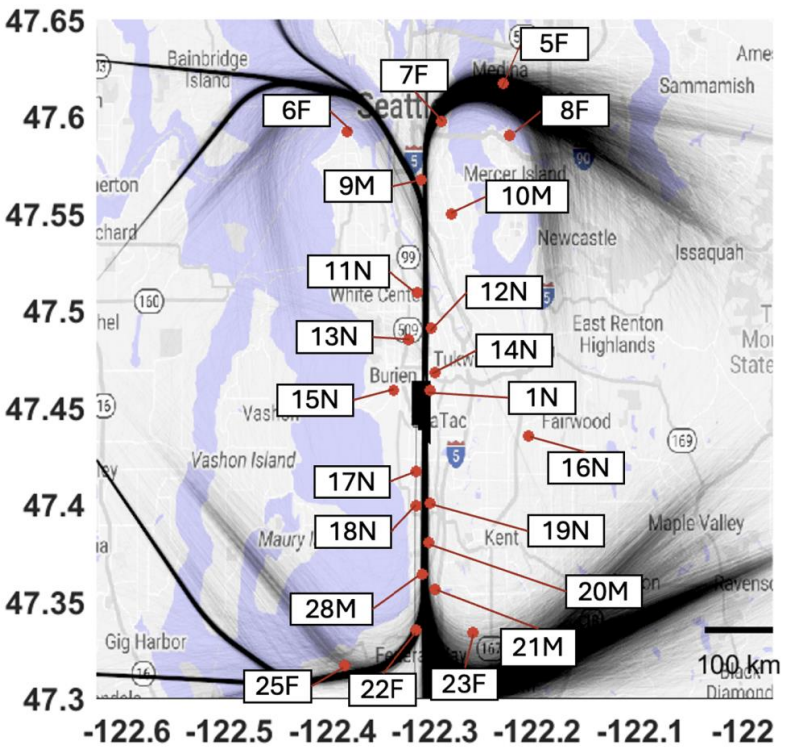


Focus Airport Noise Monitors & Flight Data



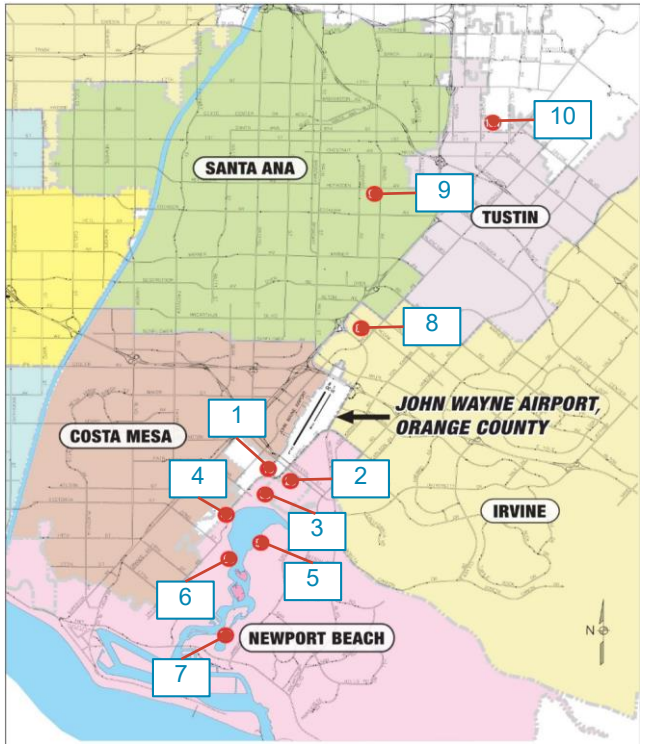
BOS

Sep 2022 – Aug 2024
(2 years)



SEA

Nov 2021- Sep 2024
(3 years)

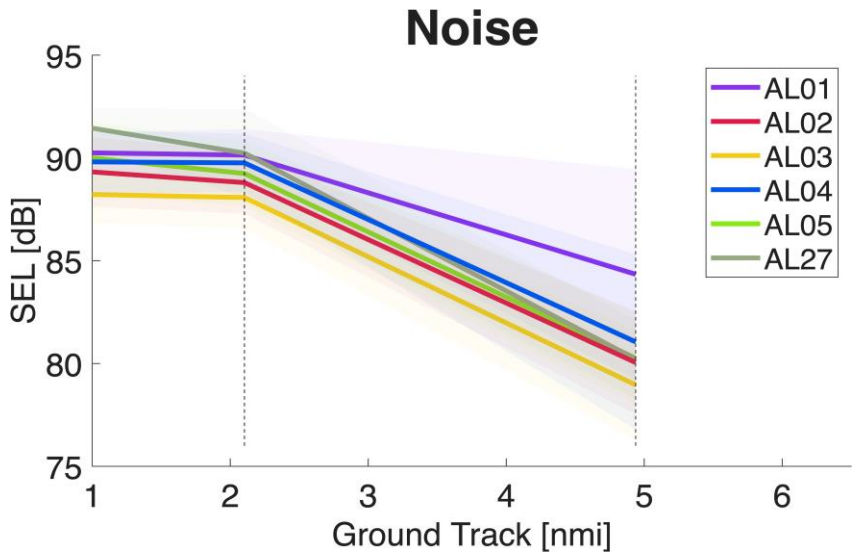


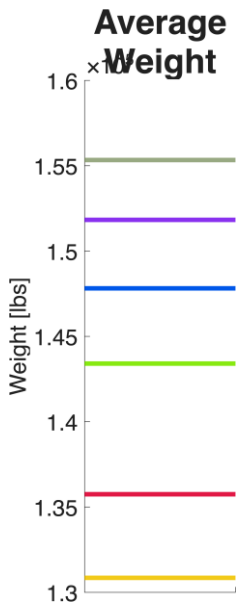
SNA

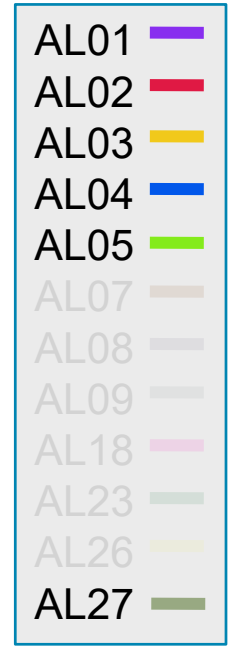
Jan 2022 – Dec 2024
(3 years)

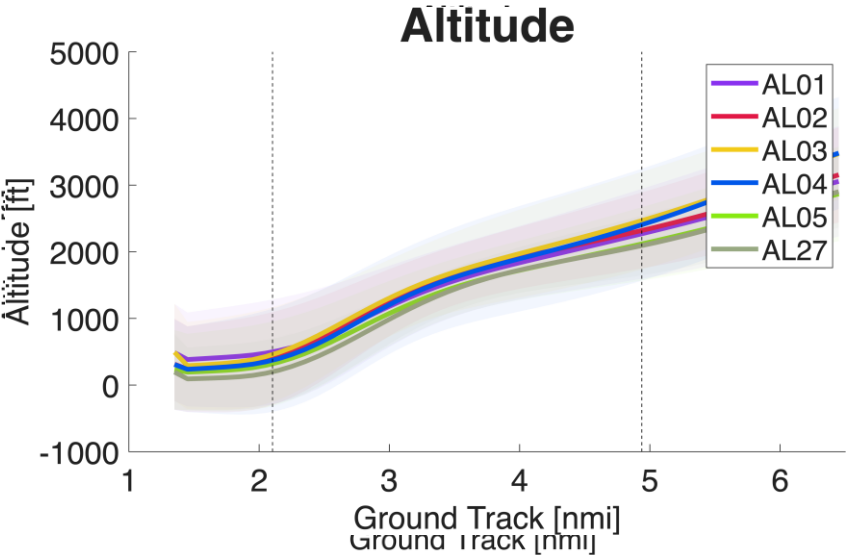
KBOS 33L Departures B737-800

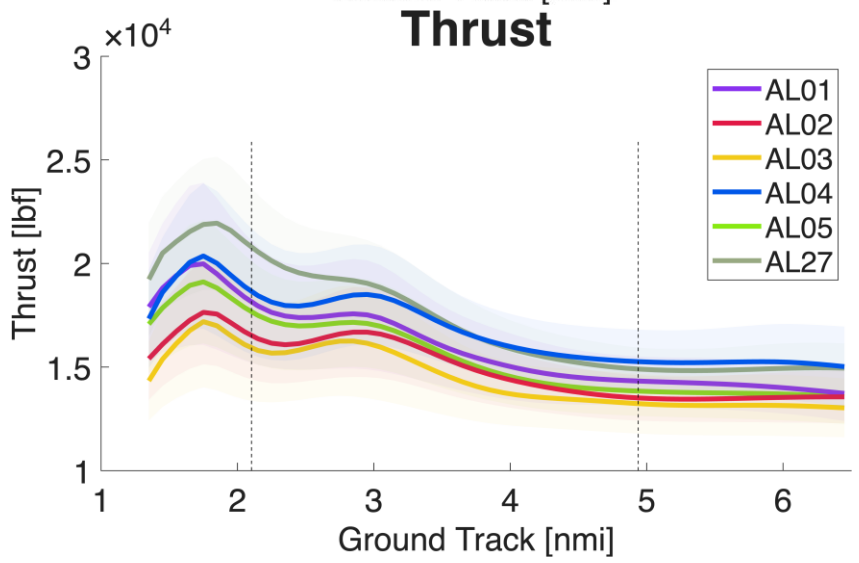
- AL27 High initial thrust, noise

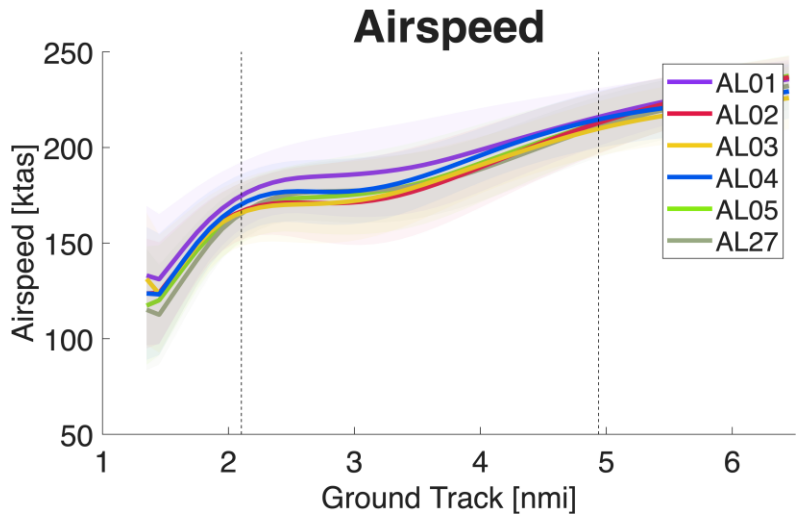






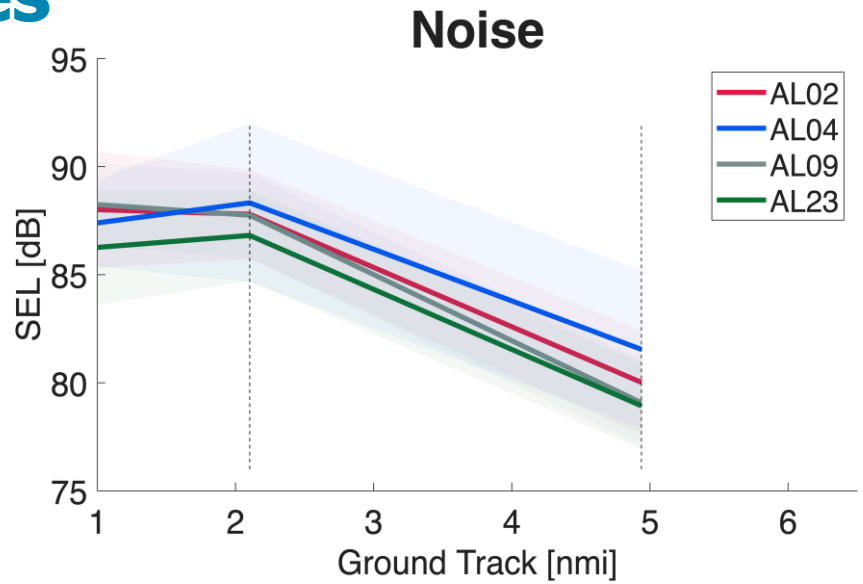


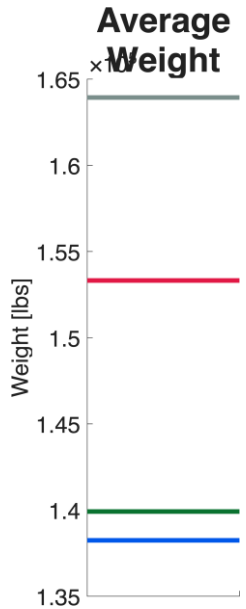


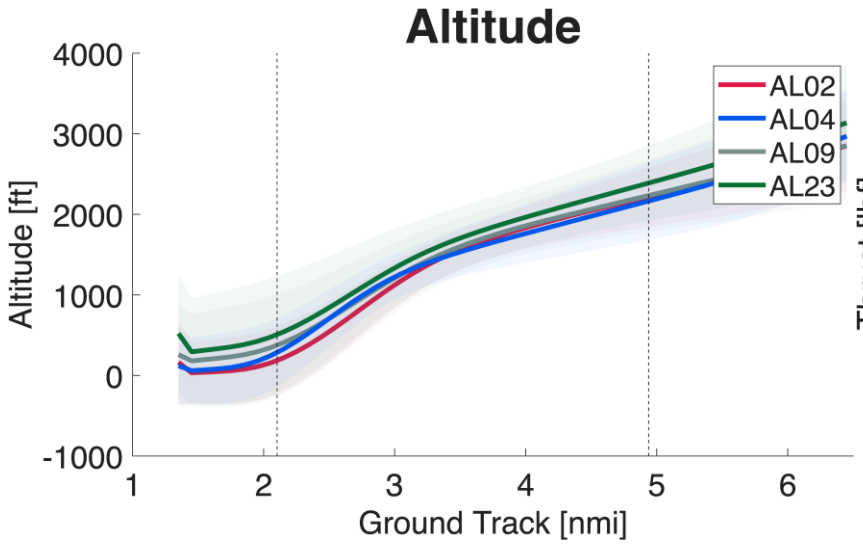


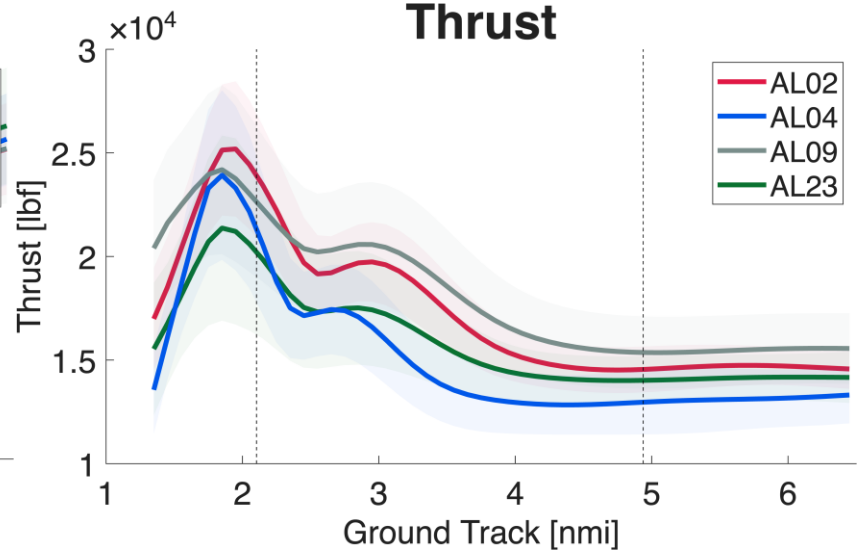
KBOS 33L Departures A320

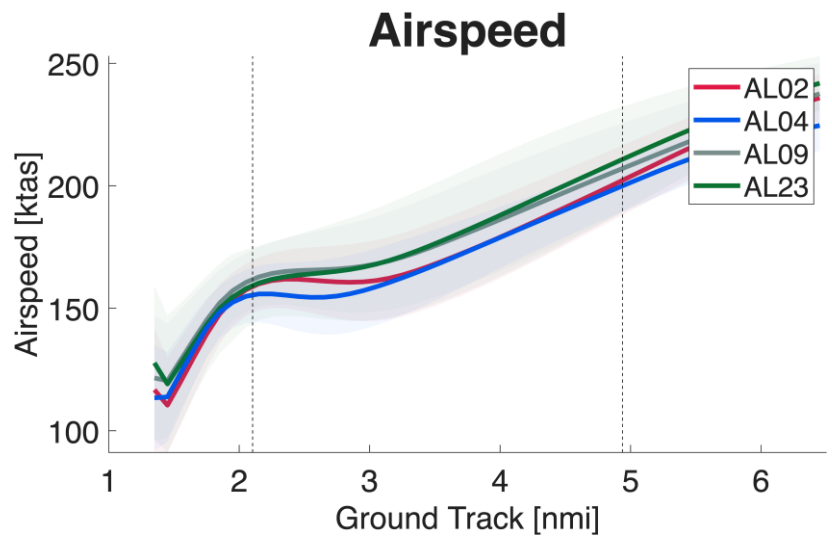
- AL9 high weight but relatively low noise.
- AL 23 low weight, and noise





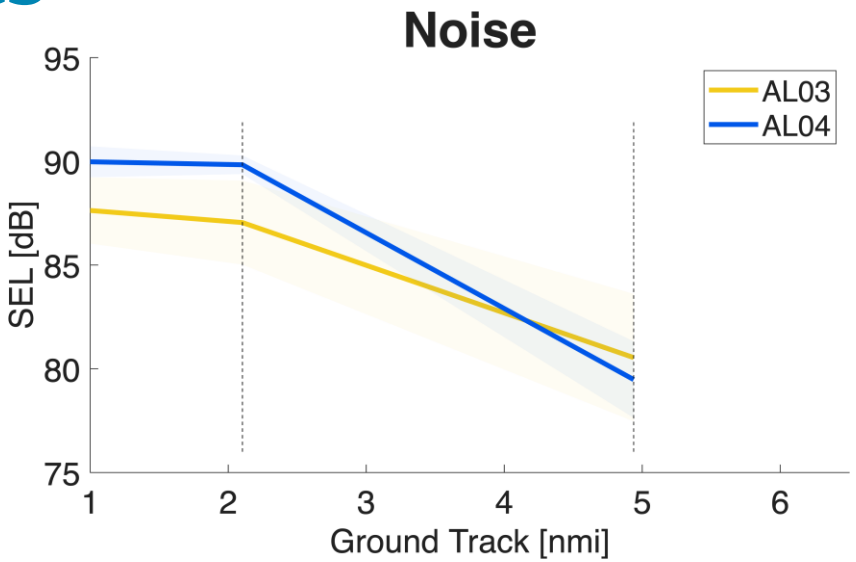


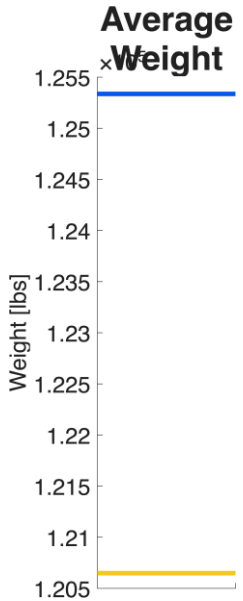


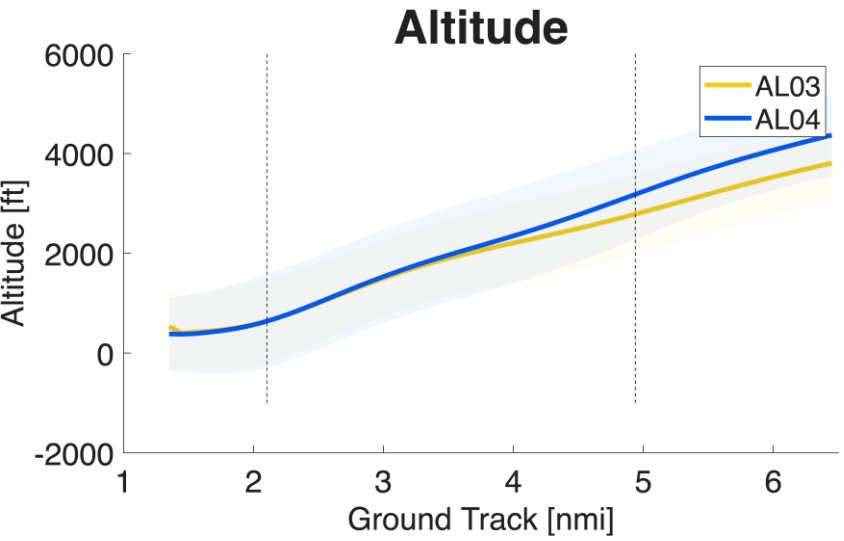


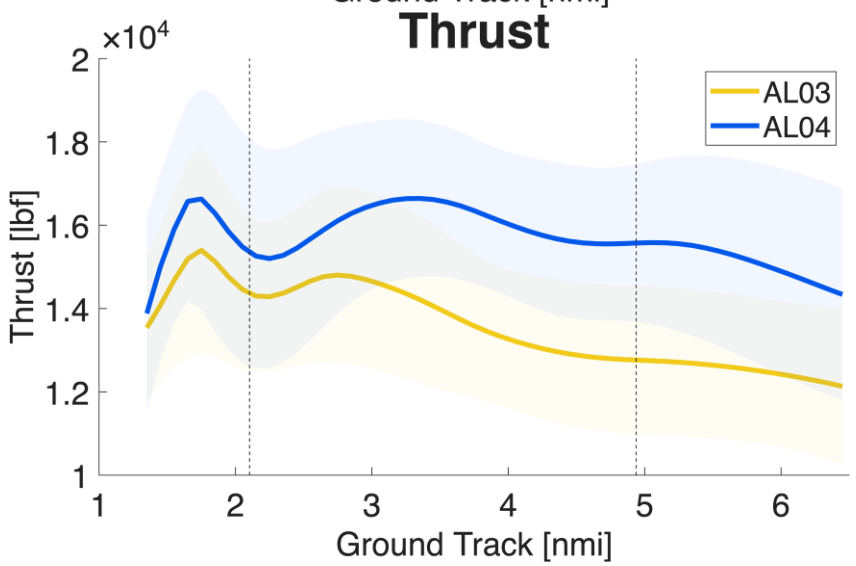
KBOS 33L Departures B737-700

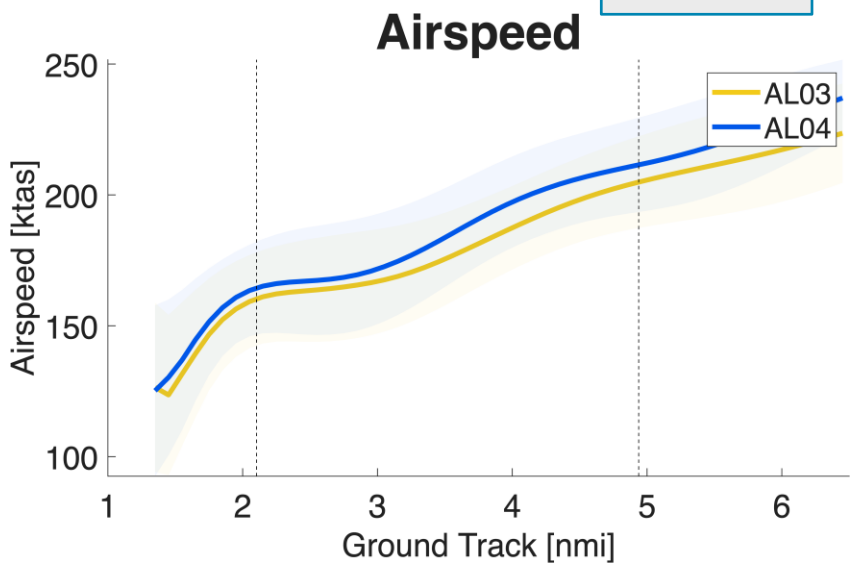
- AL4 high weight and initial thrust, noise



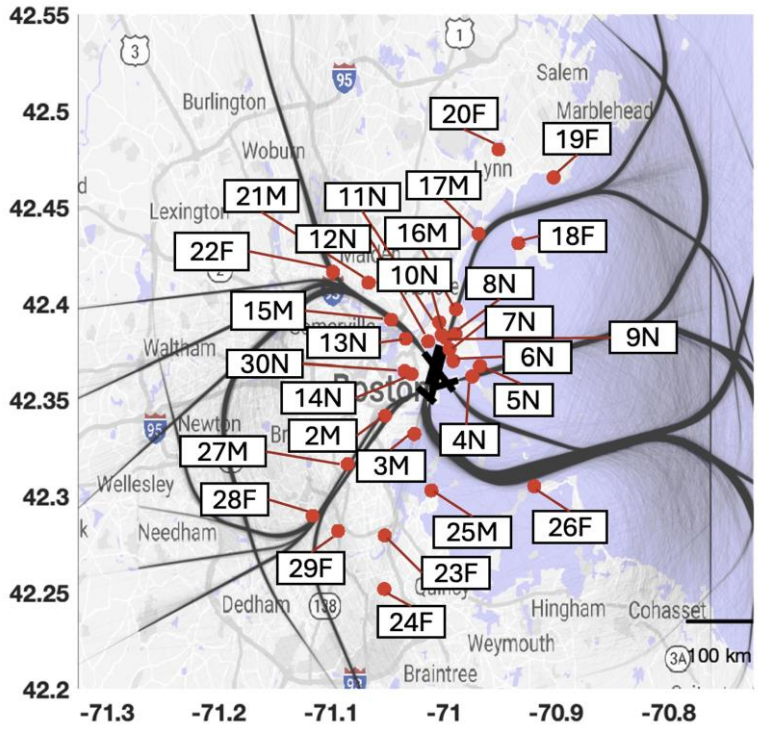






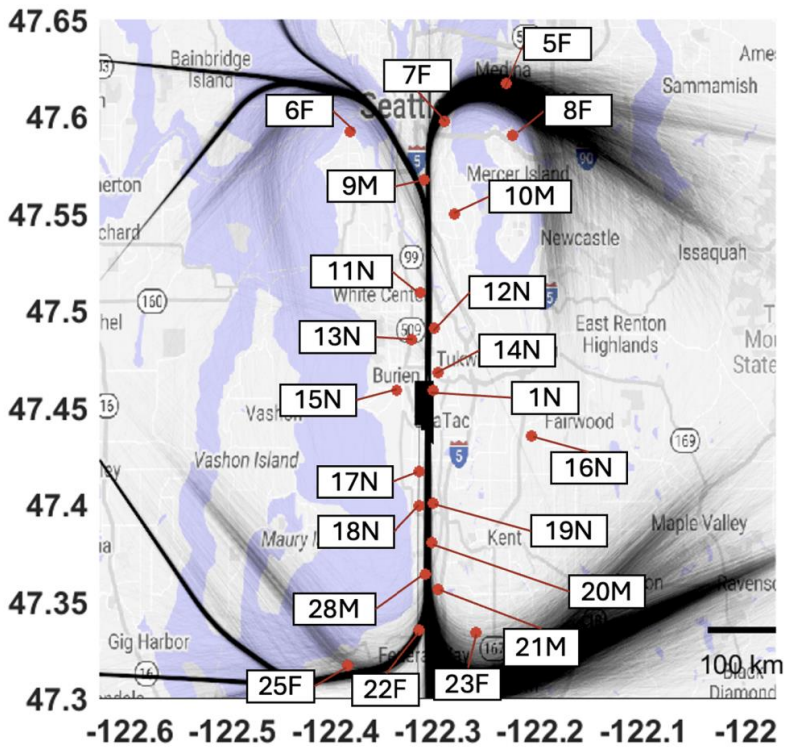


Focus Airport Noise Monitors & Flight Data



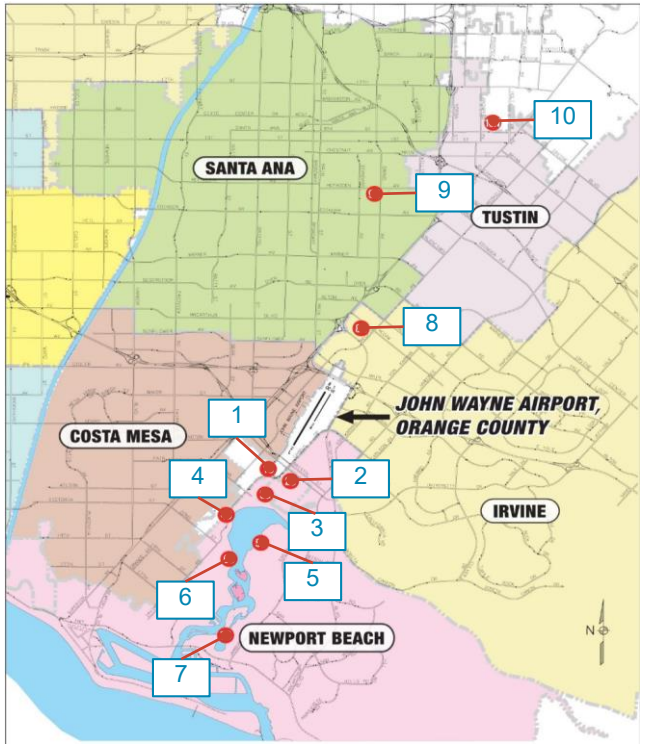
BOS

Sep 2022 – Aug 2024
(2 years)



SEA

Nov 2021- Sep 2024
(3 years)



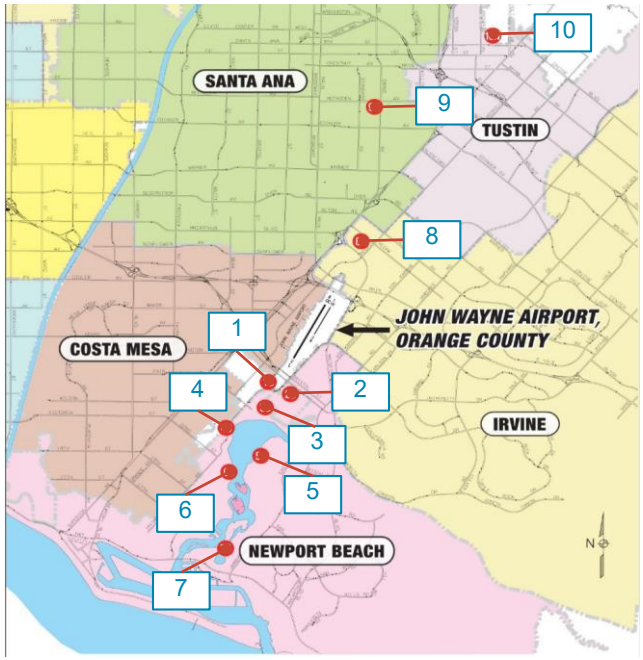
SNA

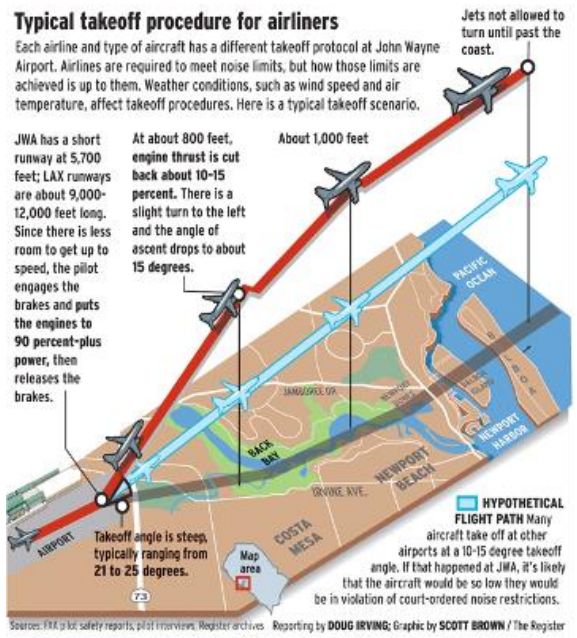
Jan 2022 – Dec 2024
(3 years)

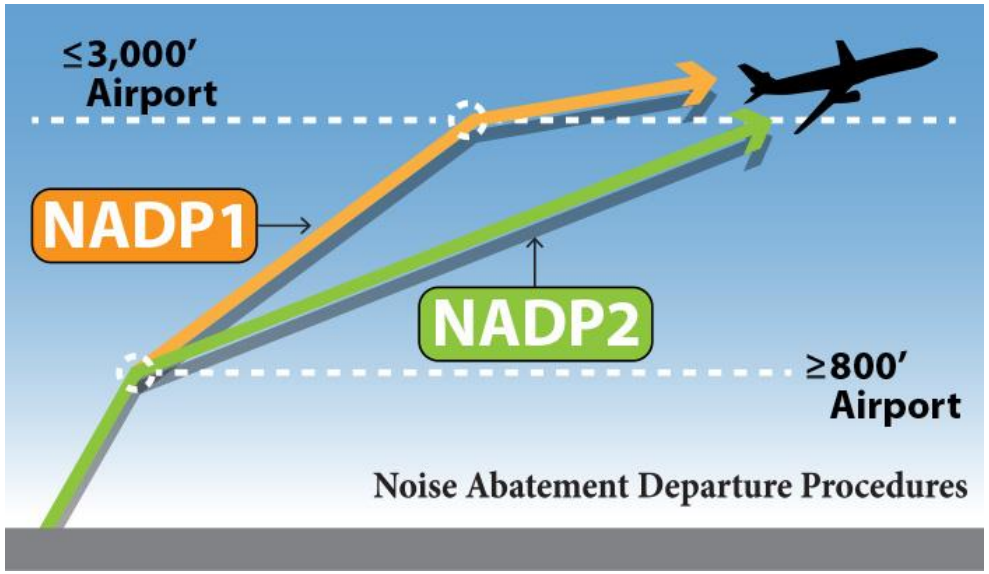
SNA John Wayne Special Noise Abatement Environment

- Surrounding area is highly noise sensitive – court order restricts 89 dB limit over specific noise sensor, airline discretion to meet limit

Note: Strict adherence to the modified procedure is essential for noise considerations, avoiding fines, and operational impact for the Company.

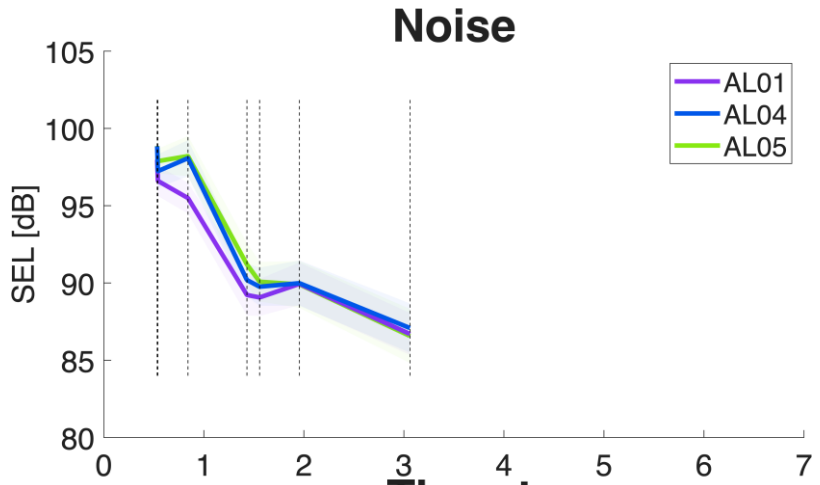


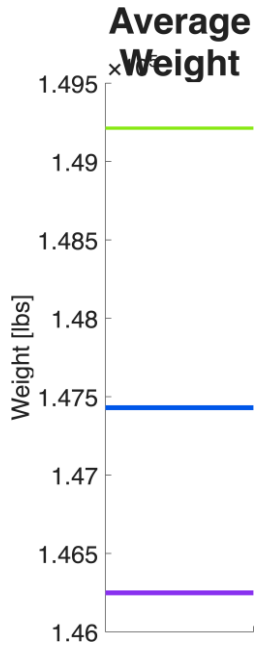


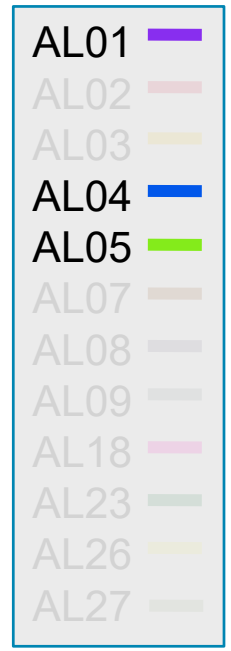


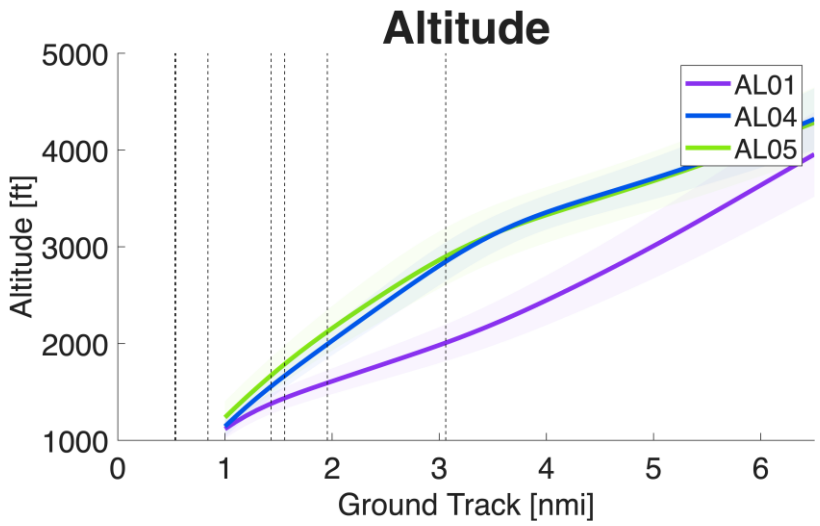
Case: KSNA Southbound Departures, B737-800

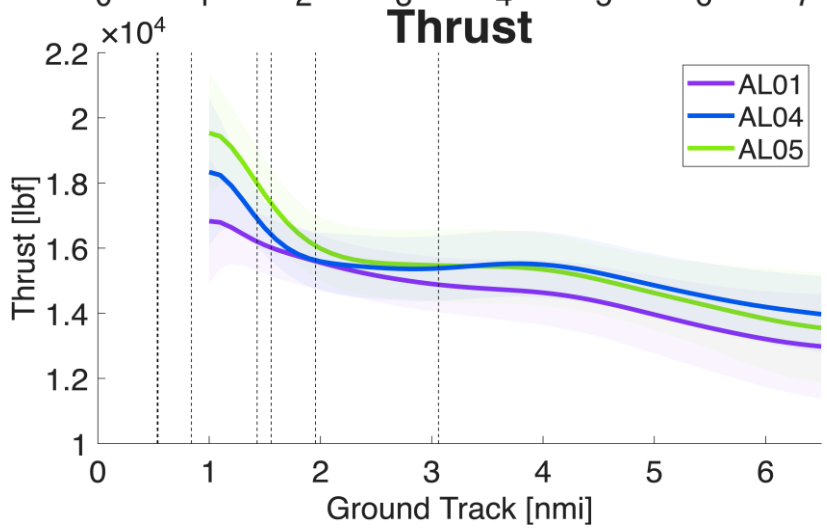
- AL1 Modified NADP1
- AL 4&5 NADP 2 like

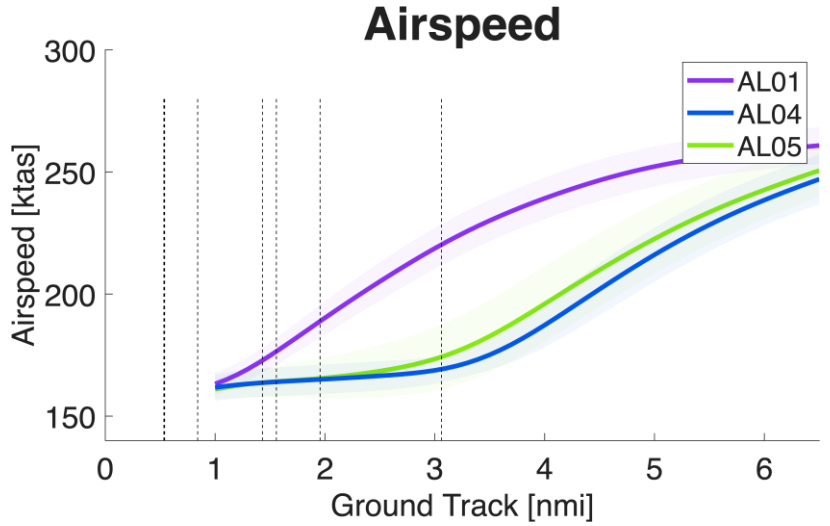






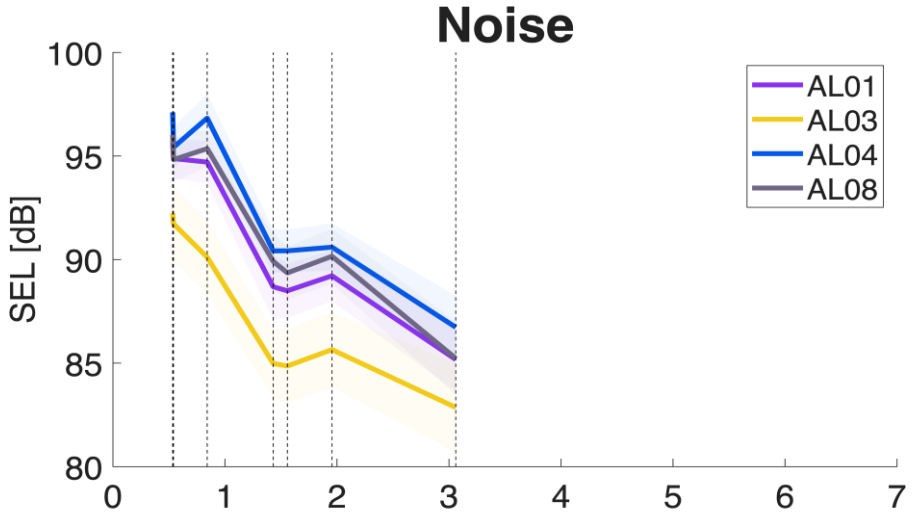


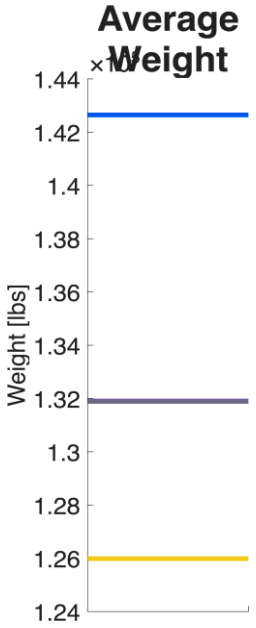


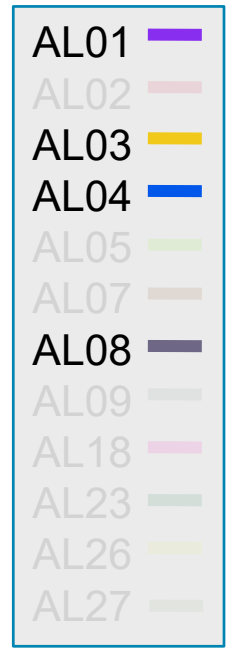


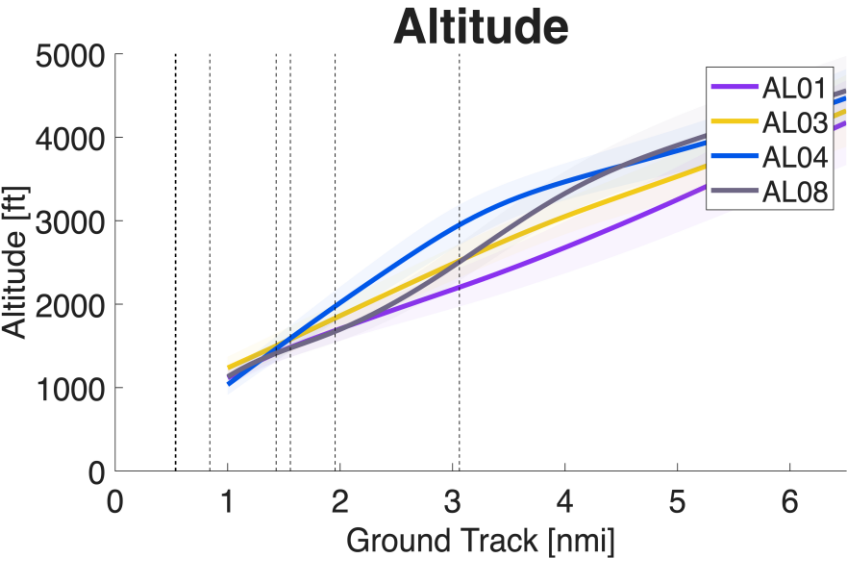
Case: KSNA Southbound Departures, B737-700

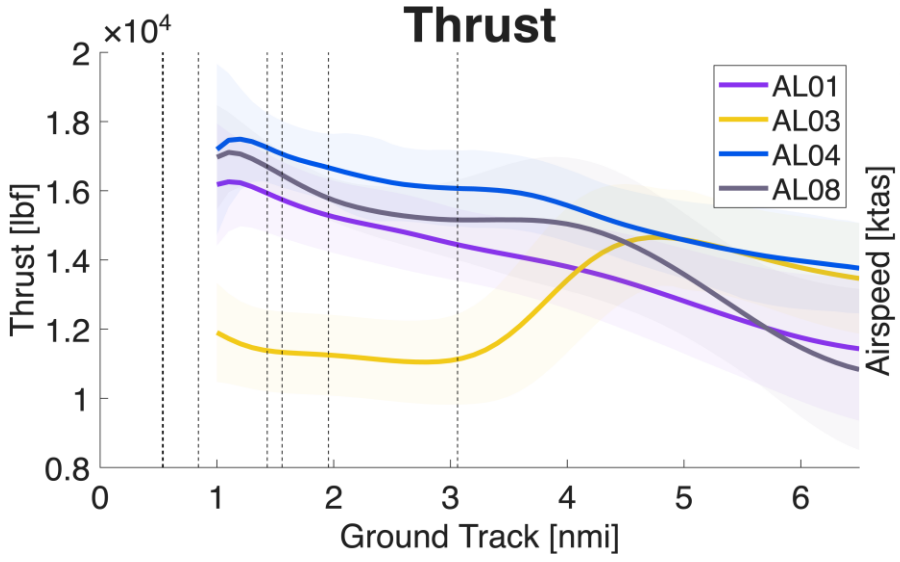
- AL3 Power cut back over monitors

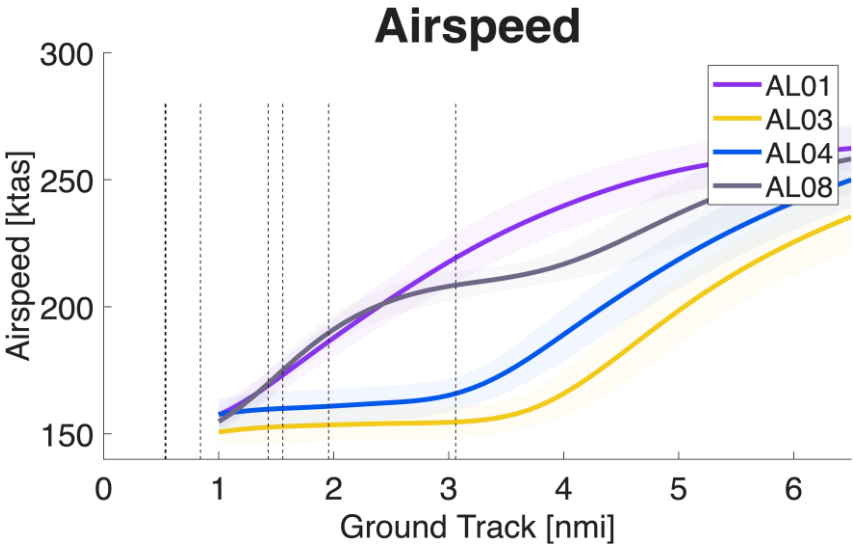






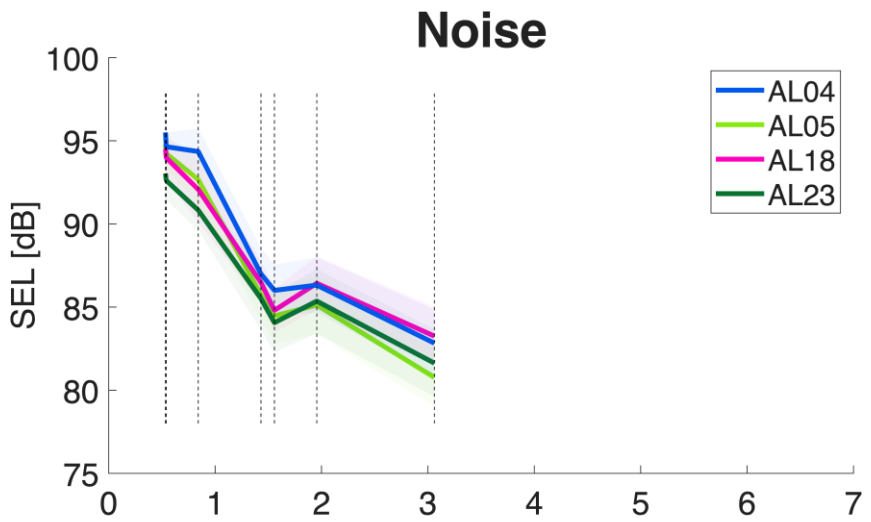


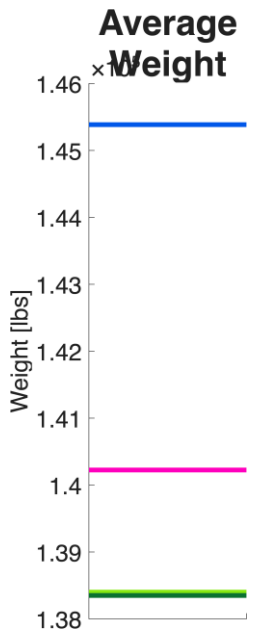


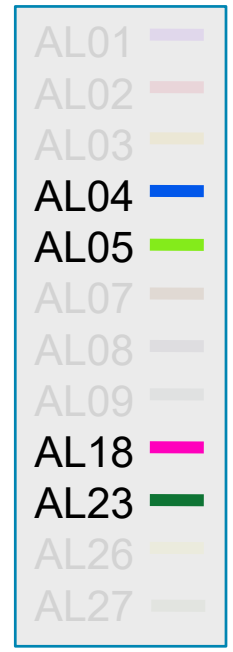


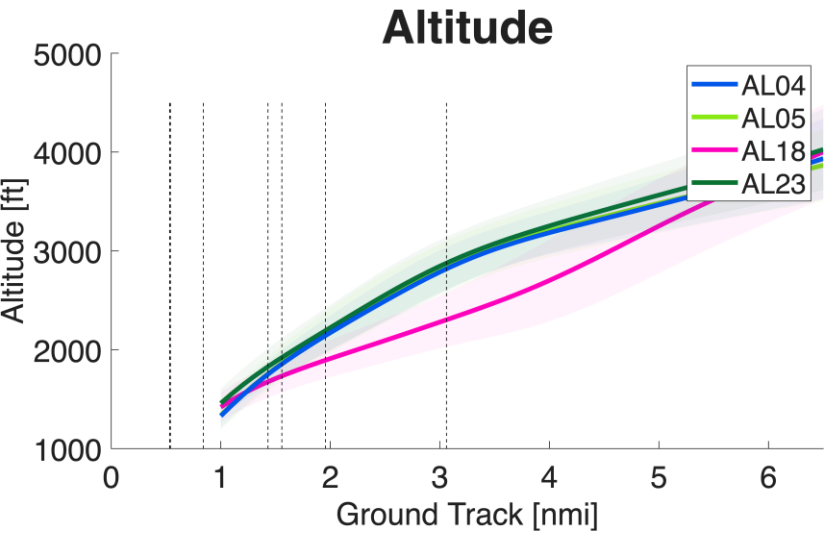
Case: KSNA Southbound Departures, A320

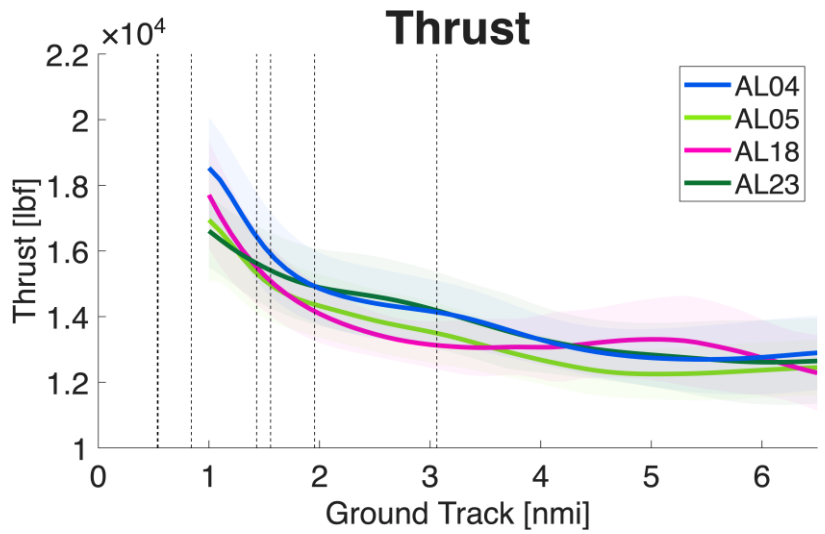
- AL18 Modified NADP1
- Others NADP 2 like

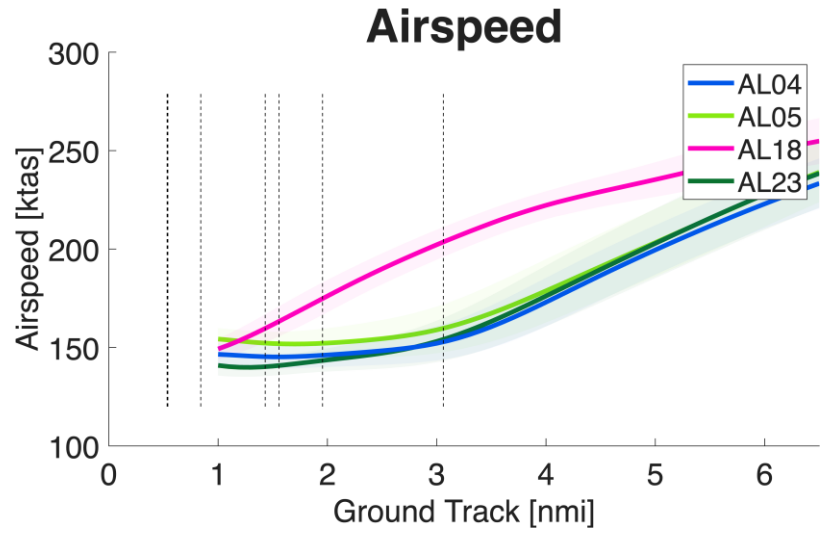












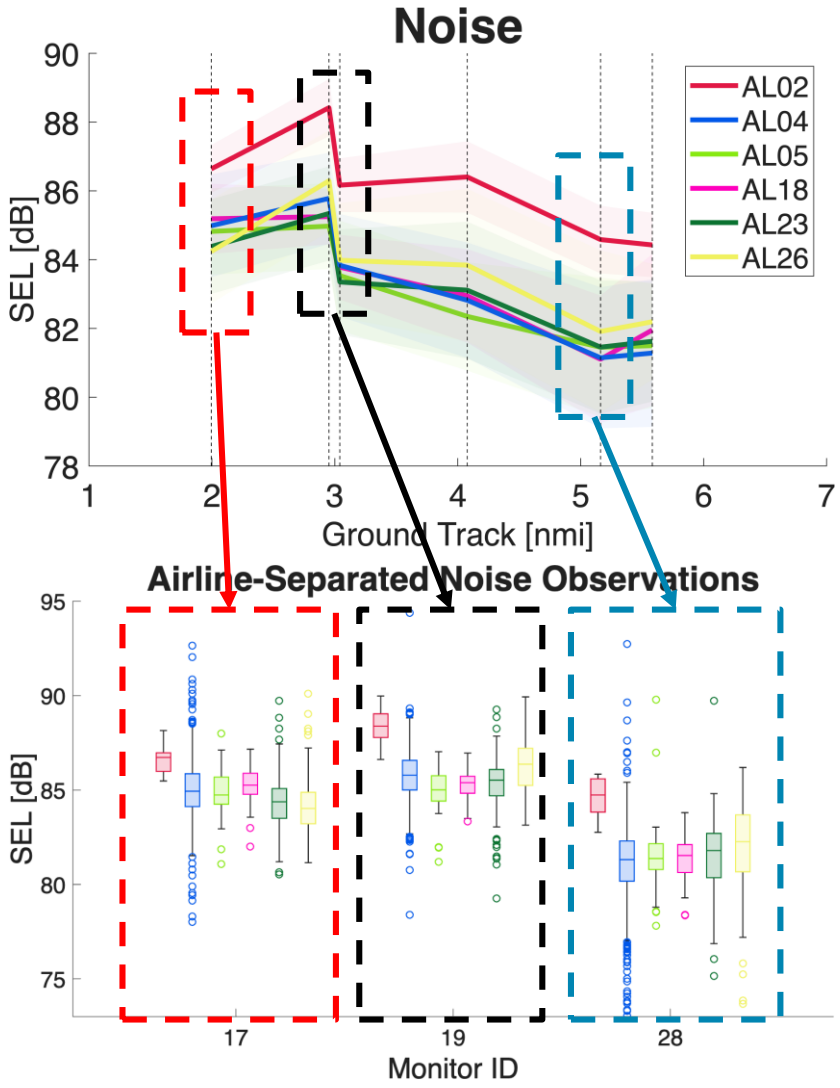
Evaluating High and Low Noise Outlier Flights

- Initial analysis focusing on high noise tail numbers
  - Assuming certain aircraft have anomalous source noise – e.g. fuel vent ports on A320s
  - These should appear as outliers on the distribution of noise results at monitors

- To identify: group noise observations by airline – aircraft at each monitor
  - Outliers flagged as observations which are more than $\geq 1.5 \cdot IQR$ outside of the 25th – 75th percentile range at any monitor
  - Standard practice to identify outliers on a box and whisker plot
  - Grouping by airline removes procedural differences

- Outlier observations can then be aggregated across different monitors to identify more common outliers

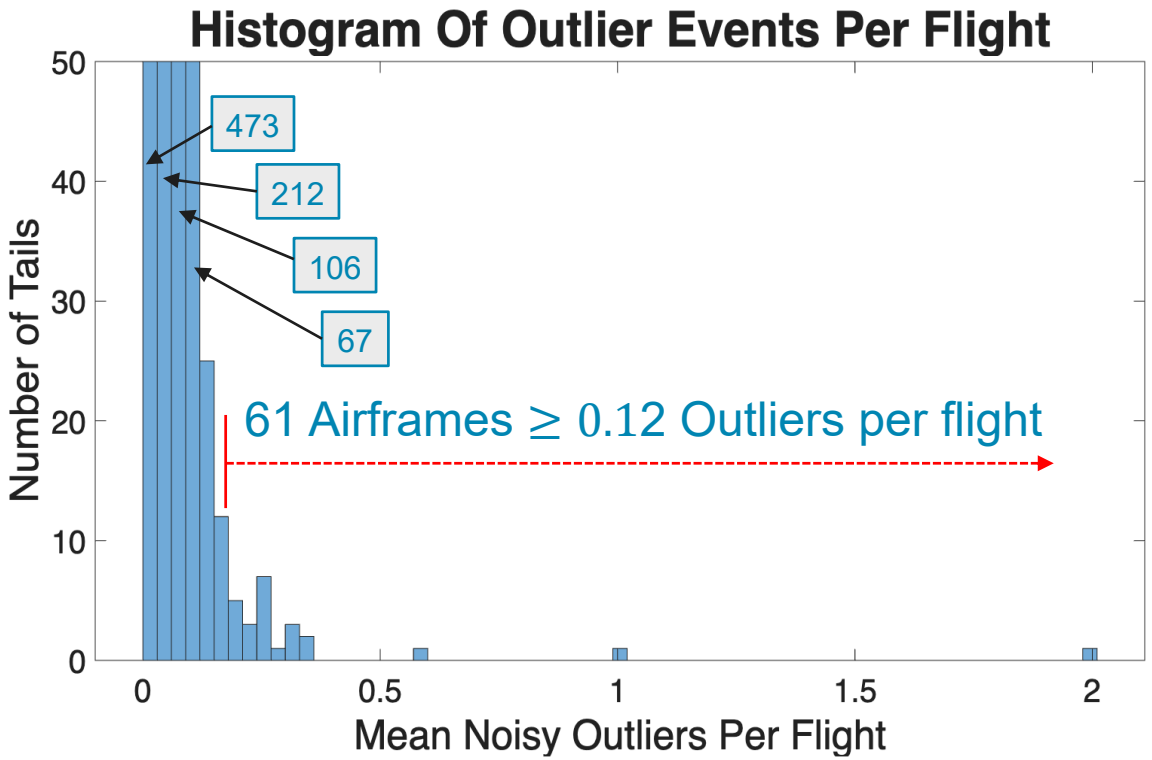
KSEA A320 Departures



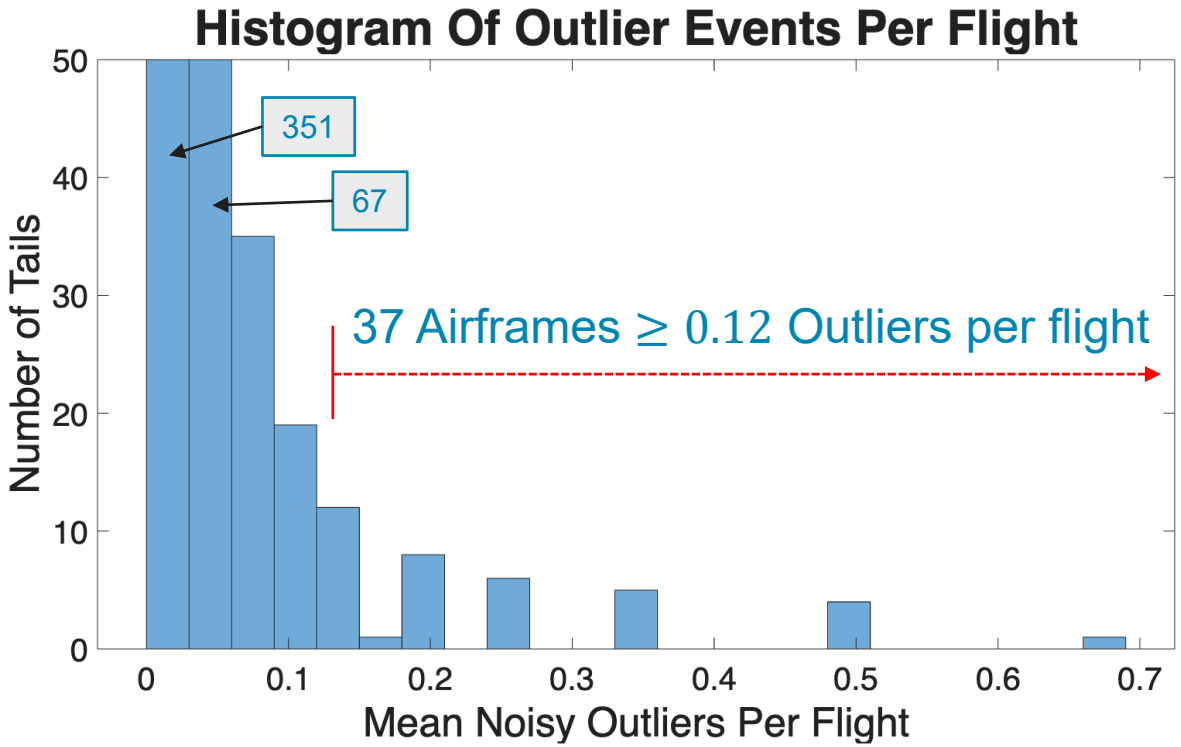
Preliminary Identification of Noisy Airframes

- For each tail number, the average number of outlier events per flight for all operations is tabulated
- The airframes with the most outlier events per flight identified for further investigation
  - Trends in outlier events per flight to be investigated for noisy airframes

B737-800 All Operations



A320 All Operations



Questions?