Noise Power Distance Re-evaluation

Project 43

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ASCENT
AVIATION SUSTAINABILITY CENTER

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Noise Power Distance Re-Evaluation

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Cost Share Partner: Industry in-kind

Objective:

Construct an NPD correction function for implementation in AEDT to account for changes in source noise due to flight configuration, speed from the baseline conditions

Validation against available measurement data

Project Benefits:

- Improved noise predictions due to changes in configuration and speed in AEDT further away from the airport
- Enhance the accuracy of AEDT through improved aircraft source noise prediction and modeling

Research Approach:

- ANOPP is used to capture configuration-related noise results for range of engine parameters across different aircraft classes
- Regression model is generated to calculate difference between baseline NPD and specific aircraft configuration NPD
- Correction function is implemented with FOQA data in AEDT and validated against real-world noise monitor data

Major Accomplishments (to date):

- Designed correction functions for 50, 150, 210, and 300pax aircraft classes
- Validated 150pax correction function against real-world noise monitor data at SFO; simulated tracks using the correction function resulted in noise readings closer to the noise monitor readings than default AEDT simulated tracks for 7/11 cases

Future Work / Schedule:

- AEDT corrected NPDs will be compared against high fidelity data to ensure accuracy
- Provide initial implementation plan for AEDT to developers and refine based on feedback for all classes

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Project 43

- Motivation
  - NPD method within AEDT was developed decades ago with little flexibility to account for airframe noise and speed effects
  - Away from airports and for different flight segments, assumptions become less robust
- Project Impact
  - Enhance the accuracy of AEDT through improved aircraft source noise prediction and modeling
  - Needed to support the evaluation and development of aircraft flight procedures that could reduce community noise
  - Facilitate the implementation of NextGen through improved characterization of the noise benefits it would deliver
- Objectives
  - Study representative fleet mixes and aircraft types
  - Validation against available measurement data
  - Investigate a method to effectively represent the fleet
  - Maintain compatibility with existing NPD (integrated modeling) approach

Project Timeline

- Year 1
  - Modify AEDT source code – formulate NPD+C implementation approach
  - Use EDS/ANOPP2 to predict impact of NPD+C
  - Sensitivity study on fleet size / noise sources vs. SEL contour area
- Year 2
  - Determine if linear correction function to baseline NPD feasible approach
- Year 3
  - Validate approach against airport monitor data
  - Use flight data to reduce/quantify impact of error in source noise prediction
  - Collaborate with Penn State to provide source noise models to test their propagation models
- Year 4 **- This year**
  - Develop and validate NPD+C correction function
  - Develop an AEDT implementation plan

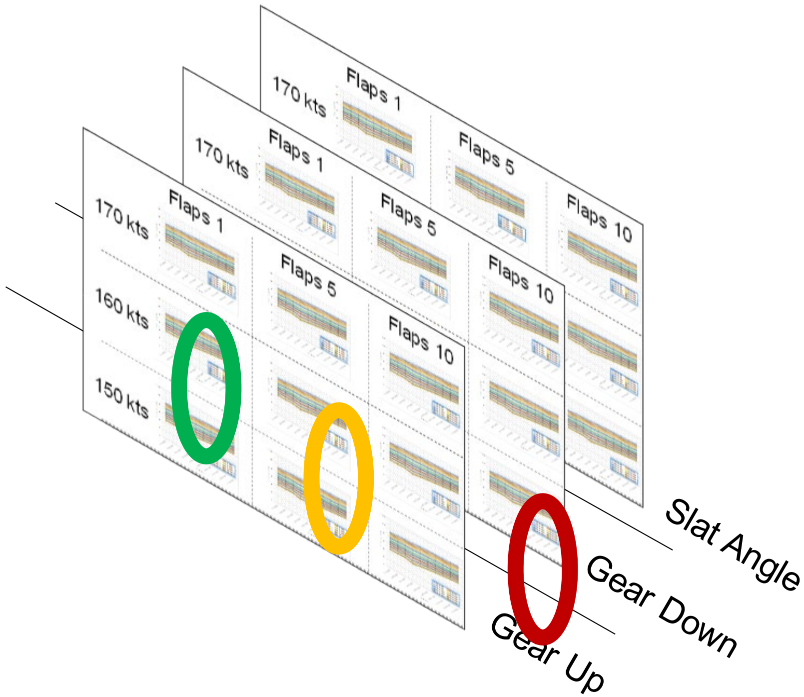
Project 43

- Opportunities and Interactions
  - SAE A-21: Shared progress with community, received feedback on approach
  - Overlap with PSU project
  - Ongoing discussion with NASA (ANOPP), Volpe, Wyle (DIA data), and Boeing (NPD data)
  - EDS/ANOPP working experience and ongoing validation of modeling
  - Further development and 'draft' enhancements to AEDT
- Project Outcomes
  - Modified AEDT sample code to be capable of accepting multiple NPDs
  - Modified AEDT sample code to output individual segment contribution to SEL grid
  - Identification that speed during approach was the major contributor to SEL area change
  - Framework for accepting NPD+C data from any source

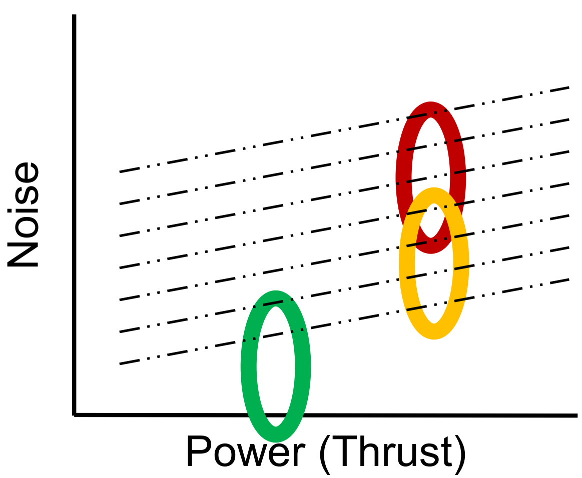
Assumptions and Practices used in Project 43

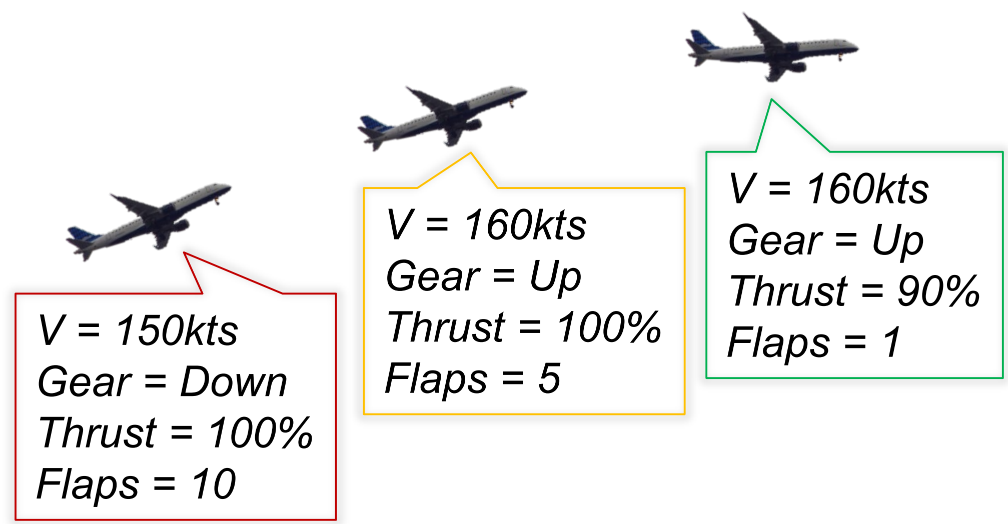
- Used standard procedures within AEDT
- Used default AEDT vehicle performance (not EDS definitions)
- Used standard day and atmosphere (no spectral effects)
  - Sensitivity analysis revealed minimal effects from multi-configuration spectral effects
- Focused solely on configuration and speed impact on source noise via NPD
- Not focused on validating tools and software
  - Trust NPSS, ANOPP2, AEDT tools as evident through wide usage in government and industry
- Important: a reference condition for speed, flap setting, and gear location was assumed for each vehicle class

Custom Source Noise Profile

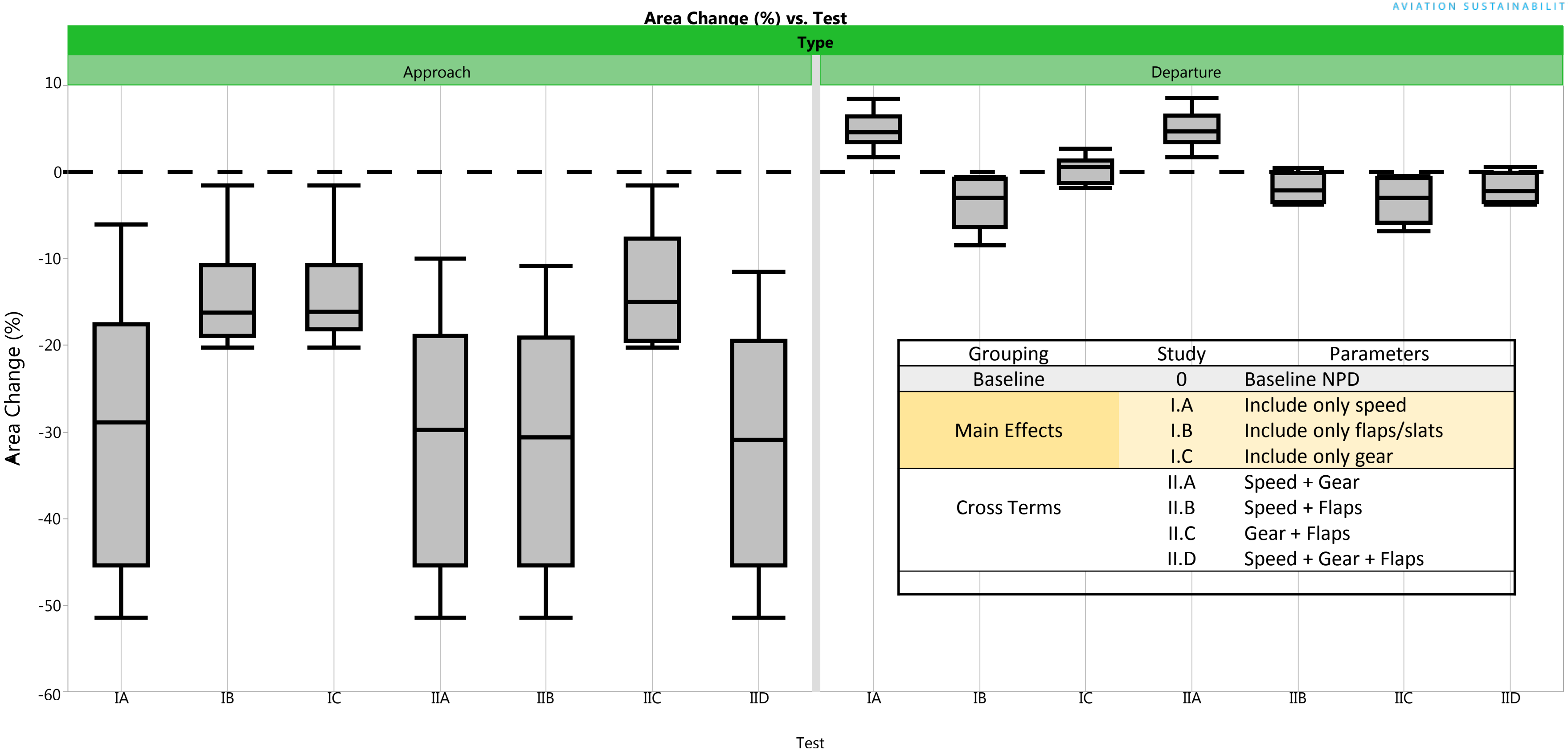


- Depending on flight profile and vehicle configuration interpolate to:
  - Calculate change in NPD based on segment by segment basis
  - Ensures consistency with AEDT noise calculation method
  - Requires modification to the AEDT source code



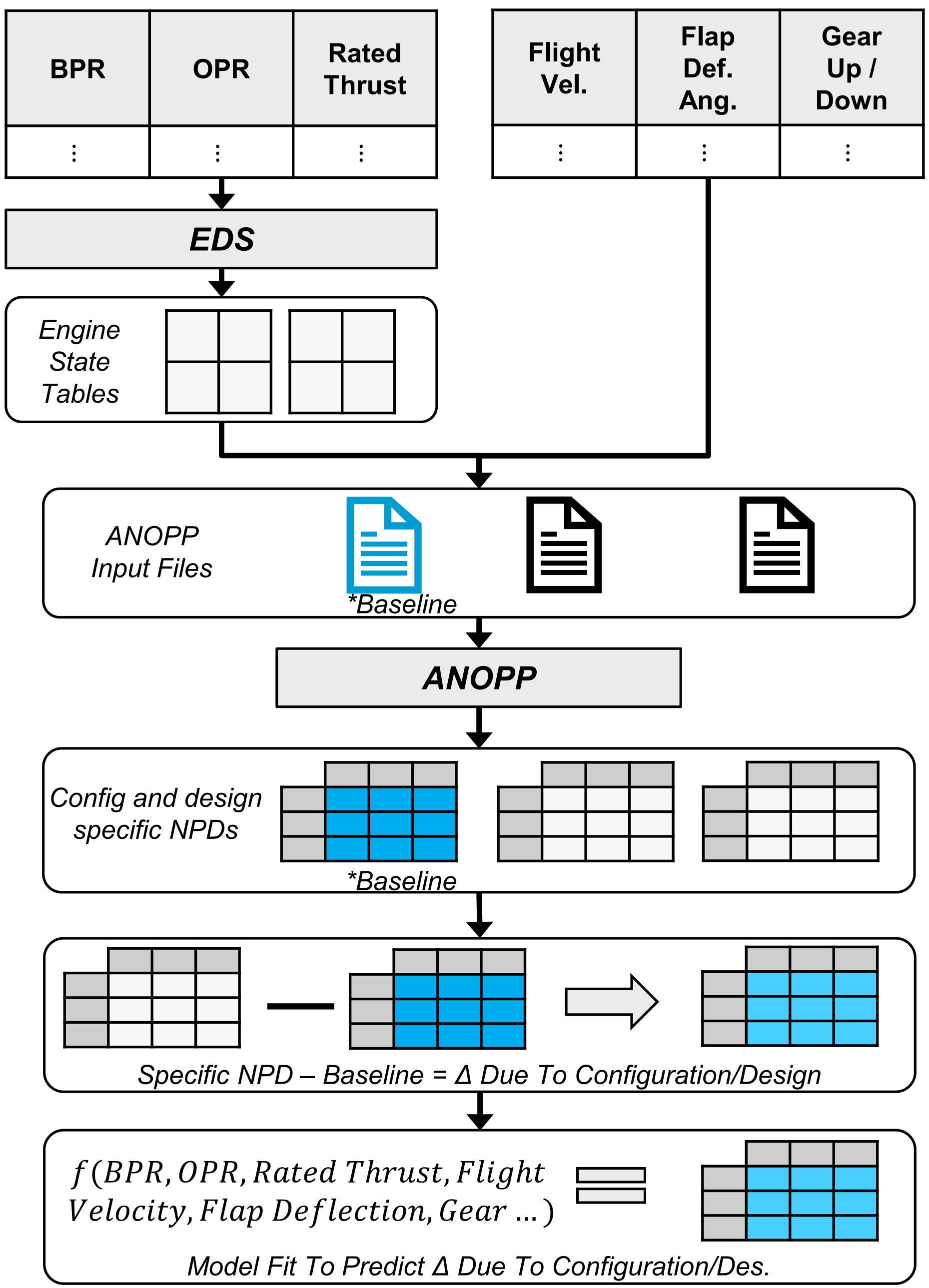


Summary of Key Findings

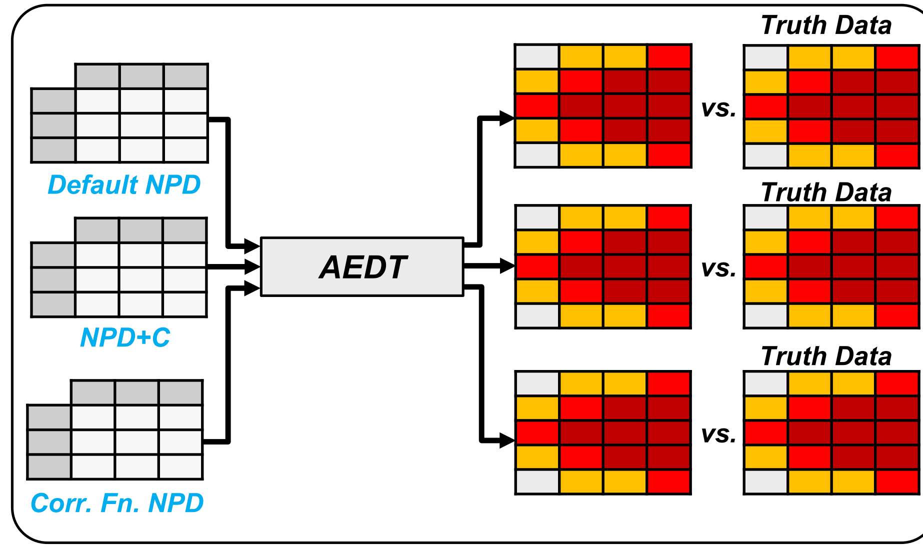


- The presence of the speed dimension in the NPD+C curves has the most significant impact in the overall noise contour obtained from running the modified AEDT environment
- Departure procedures are less affected by the modifications
  - Jet source noise is dominant
  - Velocity corrections at higher reference speeds are negative
- Impact is mostly an area decrease difference due to:
  - Changes in source noise with velocity
  - The velocity corrections having a great impact in the final total SEL value for the given grid point

Correction Function Generation



Correction Function Validation



Running trajectories in AEDT with <u>default NPDs</u>, ANOPP-generated <u>NPD+Cs</u>, and <u>correction function-adjusted NPDs</u> to compare with SFO truth data. Three aircraft chosen for initial checkout:

***Original Aircraft (ex: 737-800)**;*
- *Can correction function accurately account for configuration changes?*

***Aircraft Variant (ex: 737-900)**;*
- *Can correction function be applied to variants of the same aircraft?*

Different Aircraft in Same class (ex: A320);
- *Can correction function be applied to different aircraft in same class?*

Assessing which method provides the most accurate noise prediction compared to the truth data, and if correction function can be used across wider range of aircraft

C.F. General Form

General C.F. Form:

$$\boldsymbol{CF(BPR, OPR, SLS\ Thrust, FDA, FV, Gear) =}$$

$$\boldsymbol{a * BPR + b * OPR + c * (FDA * FV)^2 + d * (SLS\ Thrust - e)^4 + \cdots}$$

Where a,b,…,e are constants

NOTE: The actual equation includes factorial terms and confounding terms (i.e. BPR^2 * BPR^3 * FDA * …) with additional terms not shown; the above representation is shown to highlight the general form. The orders of these terms range from 1-5

Accounting for Aircraft Specific Variations within Each Size Class

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	50-100pax	100-210pax	210-300pax	300+pax
BPR Range	4.3 - 6.3	4.43 - 13.78	4.2 - 9.0	4.4 - 9.23
OPR Range	17 - 28	19 - 42	22.8 - 45.4	25.4 - 48.7
SLS Thrust Range (lb_f)	7500 - 18500	22000 - 30000	48000 - 71100	70000 - 115000

AEDT database information

BPR
OPR
Thrust

ANOPP2 Empirical Equation Inputs

f_b = blade passage frequency, Hz
m = mass flow rate lb/sec
m_o = reference flow rate 1lb/sec
M_{TR} = tip relative Mach
RSS = rotor stator spacing divided by fan blade chord
ΔT = total temperature rise across the fan
ΔT_o = total temperature rise across the fan
θ = angle from inlet axis

ANOPP2 Outputs

SEL
- Broadband source noise strength
- Broadband stream source noise directivity
- Broadband stream source noise directivity

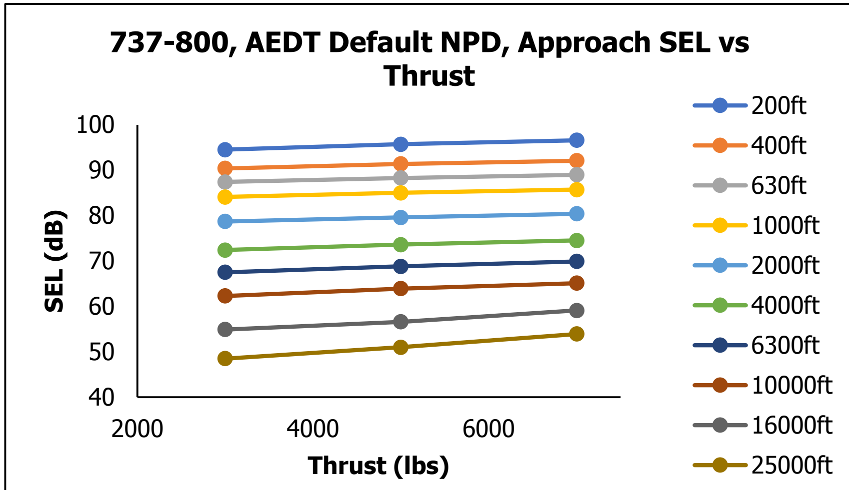
- FDA mappings for the Boeing 737-800 and ranges of validity for the 150 pax class

737800		
Flap ID	FDA	Gear
A_00	0	Up
A_01	1	Up
A_05	5	Up
A_15	15	Down
A_30	30	Down

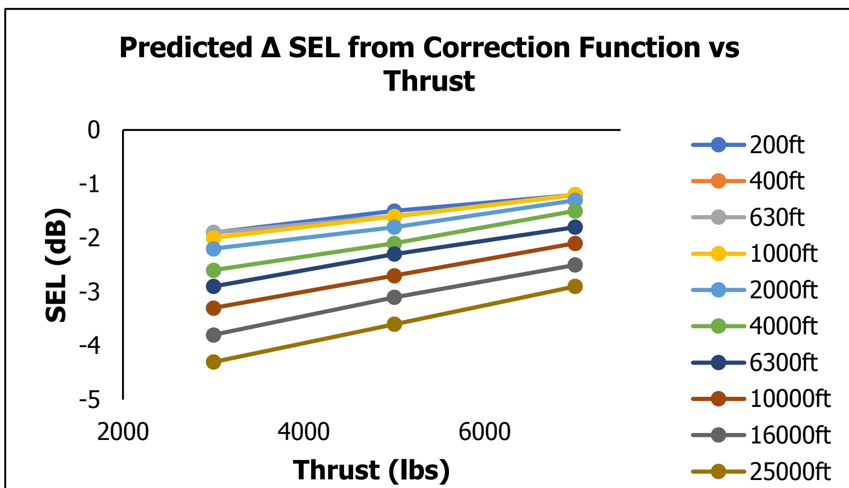
	FDA range	FV range	BPR range	OPR range	Thrust range
min	0	203	4.4347	19	22000
max	40	371	13.783	42	30000

Manufacturer variations within each class were accounted for by varying engine level parameters

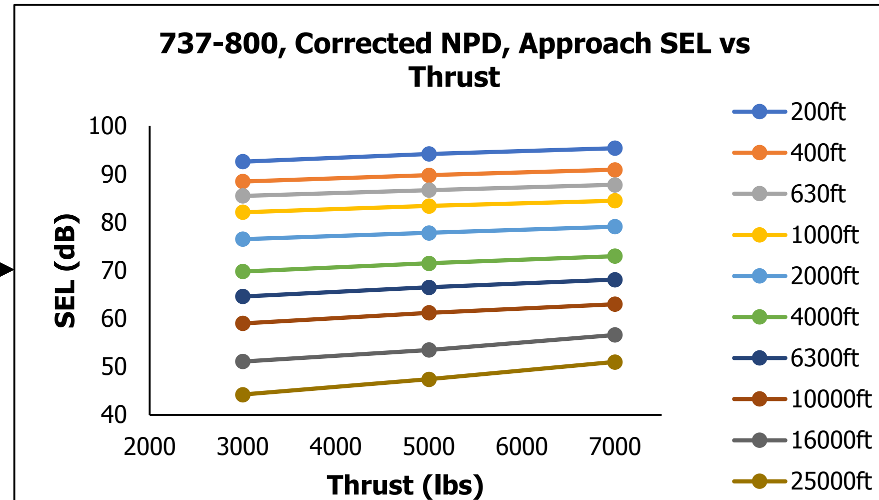
Notional Example of Correction Function Output



Default Approach NPD



Output from Correction Function



Corrected Approach NPD

- Adding the predicted noise Δ to the default NPD creates corrected NPD for a given configuration

Current Focus and Next Steps

- Current Focus
  - Creating an implementation plan for AEDT development team
    - What to modify in the source code
    - Which aircraft the CFs are applicable to
    - A key to link the flap definitions within AEDT to the CF
    - Actual CFs for each vehicle class
  - Engage with OEMs on current CFs and adjust reference condition as necessary
- Next Steps
  - Utilize the CF and apply to real world flights at SFO and compare to noise monitor data
  - Ask OEMs for review of our CF for different seat classes
  - Assess the impact of using the CF at an airport level to quantify the DNL contour level impact