

FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Noise Power Distance Re-evaluation

Project 43

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Project 43 Goals



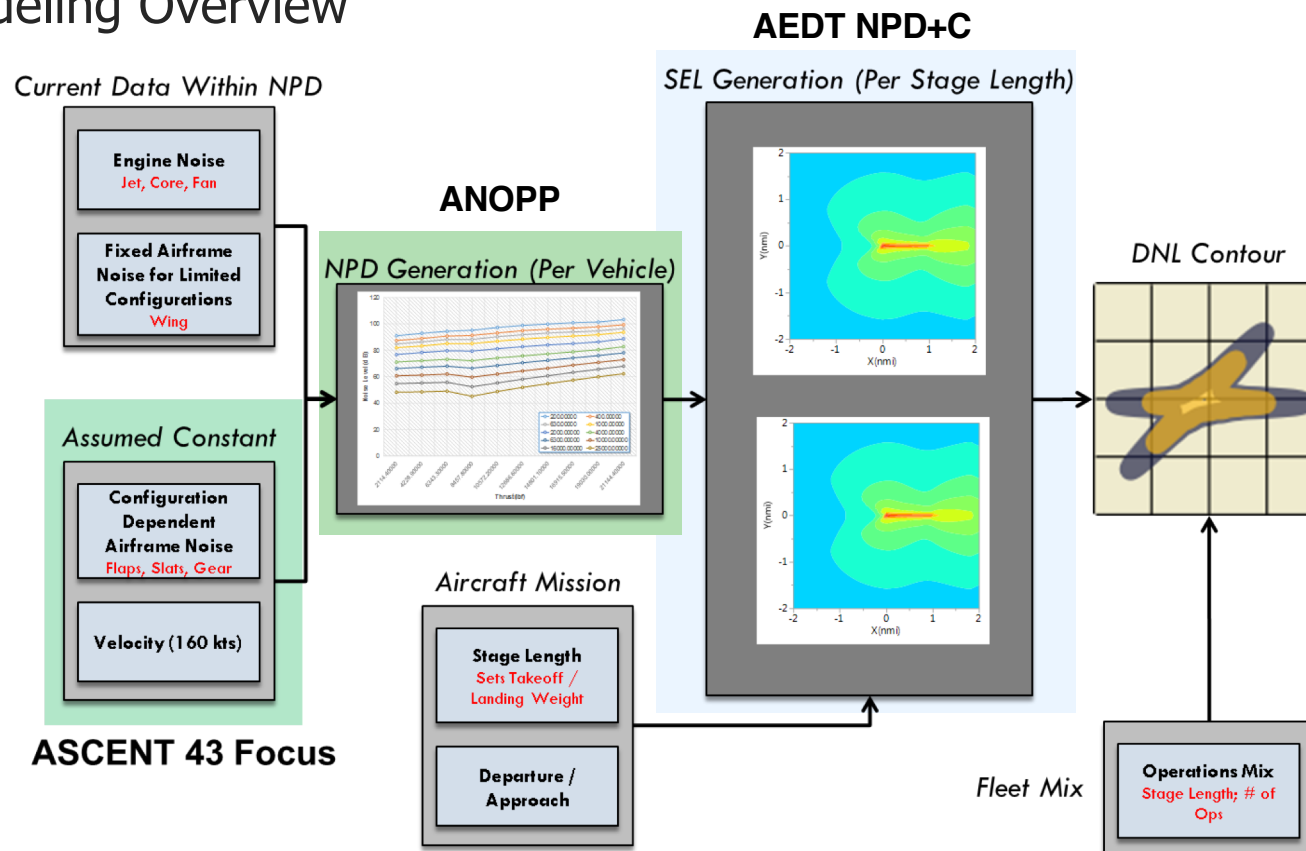
- Motivation
 - NPD method within AEDT was developed decades ago with little flexibility to account for airframe noise and speed effects
 - Away from airports and for different flight segments, assumptions become less robust
- Project Impact
 - Enhance the accuracy of AEDT through improved aircraft source 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

ASCENT Project 43 Overview (Year 1&2)



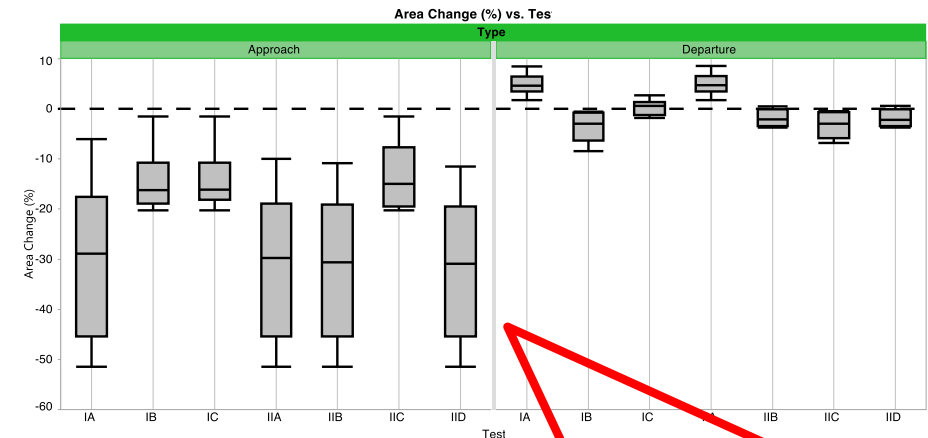
- Objectives
 - Understand the sensitivity of including aircraft configuration changes and reference speed in NPDs on resulting noise contours for 50 – 400 PAX
 - Provide physics-based recommendations on format of NPD + Configuration (NPD+C) curves for use in AEDT
 - Maintain compatibility as much as possible with existing NPD approach

NPD Modeling Overview

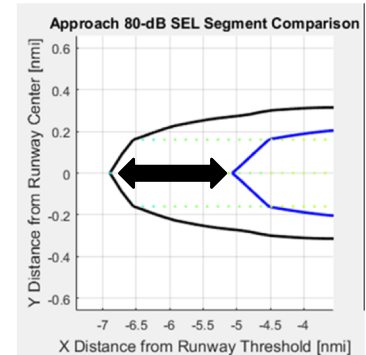


Summary of Key Findings

- Examined six aircraft classes ranging from regional jet to large wide-body
- Found effect of flight velocity on source noise to be main source of difference
- Flap noise secondary contributor
- Major differences occur during approach
 - Engine noise near maximum power dominates during departure



SEL Contour Area Variation for Approach and Departure



Grouping	Study	Parameters
Baseline	0	Baseline NPD
Main Effects	I.A	Include only speed
	I.B	Include only flaps/slats
	I.C	Include only gear
Cross Terms	II.A	Speed + Gear
	II.B	Speed + Flaps
	II.C	Gear + Flaps
	II.D	Speed + Gear + Flaps

Various Options and approaches



Integration Approach	By	Benefits	Challenges
Multi configuration NPDs (working w. mfgs)	Eurocontrol	<ul style="list-style-type: none"> From manufacturers. Considered to be well validated. 	<ul style="list-style-type: none"> Only limited models so far. Challenges to cover fleet, esp. with out of production a/c models
Fleet updated NPD+C directly from ANOPP	GT tried this	<ul style="list-style-type: none"> The process is easy to understand Consistent method for generating NPD+C 	<ul style="list-style-type: none"> Complex input parameters and delicate balance of the parameters Validation is still needed Large model library required
NPD+C via correction functions based on ANOPP	GT (Proposed approach)	<ul style="list-style-type: none"> Able to create NPD+C sets from simpler inputs (available within AEDT). No need to create ANOPP models for each a/c type. 	<ul style="list-style-type: none"> Need to consider wide condition ranges/rank orders Validation of NPD+Cs Industry buy-in

Motivates Simpler Implementation Approach

Upcoming Validation Work



- Task 1: Investigate impact of frequency content on standard NPD
 - How is spectral data used in AEDT?
 - ID what parameters to vary and how do they vary over time
 - What are the major drivers?
- Task 2: Investigate impact of frequency content along with NPD+C
 - To understand the current spectral class development process and effect when aircraft specific spectral data or even the power-setting/flap setting specific data are available.
 - Identify how to add multiple spectral data to an AEDT dep/app procedure, holding all other parameters constant for an aircraft Determine how to interpolate spectra
 - Leverage Volpe work and coordinate with aircraft manufactures to access data submitted for ANP
 - Conduct sensitivity studies using detailed spectral data available
 - Provide recommendations to the FAA on the results
- Task 3: Validate NPD+C Approach using airport noise monitoring data at a major US airport

Task 1: Sensitivity Analysis of use of Spectral Data



- Environmental impacts
 - Noise (SEL, LAmax, EPNL, PNLmax), emissions (NOx), and fuel consumption
- Weather parameters
 - Temperature, sea-level and station pressure, dew point, relative humidity, and wind speed (and cloudiness)
- Airports
 - SFO, ATL, DEN, and MEX
- Aircraft
 - CRJ900
 - B737-800 no winglets
 - B767-300ER
 - B777-200ER w/ GE engines
- Model all stage lengths with a 15,000 ft. cutoff altitude

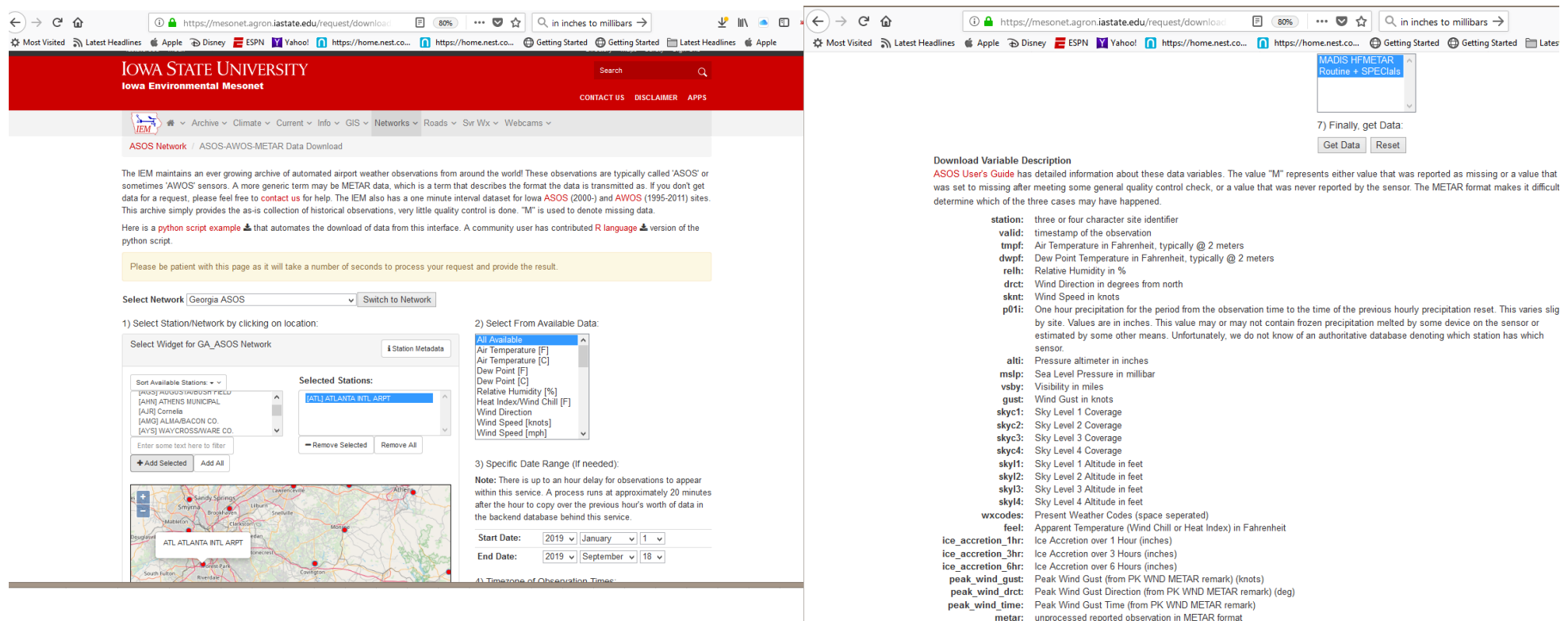
Weather Sources Example

- Weather sources

Iowa State University Environmental Mesonet

(https://mesonet.agron.iastate.edu/request/download.phtml?network=GA_ASOS)

- Weather data can be downloaded as CSV
- Daily weather data back to 1928 – needs some processing



The screenshot shows the Iowa State University Environmental Mesonet website. The left pane displays the 'ASOS Network / ASOS-AWOS-METAR Data Download' page, which includes instructions for selecting a station and date range. The right pane shows the 'Download Variable Description' page, which lists various weather variables and their units.

Select Station/Network (Georgia ASOS) [Switch to Network]

1) Select Station/Network by clicking on location:

Select Widget for GA_ASOS Network [Station Metadata]

Sort Available Stations: [All Available]

Selected Stations: [ATL] ATLANTA INTL ARPT

2) Select From Available Data:

- Air Temperature [F]
- Air Temperature [C]
- Dew Point [F]
- Dew Point [C]
- Relative Humidity [%]
- Heat Index/Wind Chill [F]
- Wind Direction
- Wind Speed [knots]
- Wind Speed [mph]

3) Specific Date Range (if needed):

Note: There is up to an hour delay for observations to appear within this service. A process runs at approximately 20 minutes after the hour to copy over the previous hour's worth of data in the backend database behind this service.

Start Date: [2019] [January] [1]

End Date: [2019] [September] [18]

4) Timestamp of Observation Times:

Download Variable Description

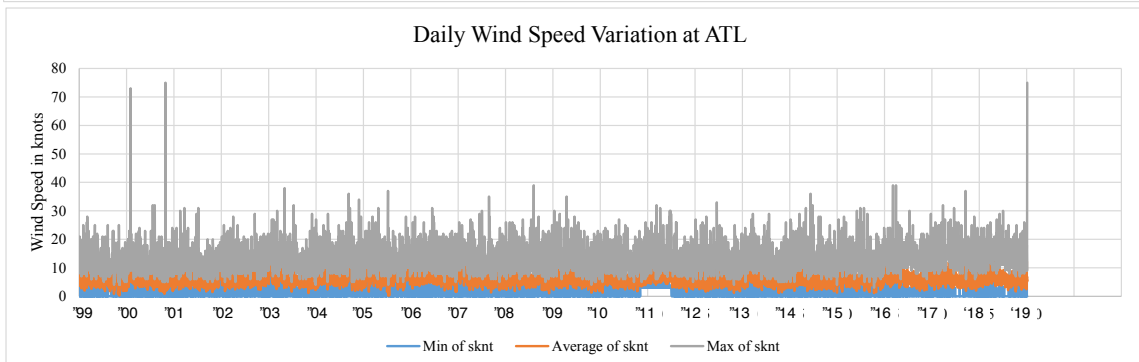
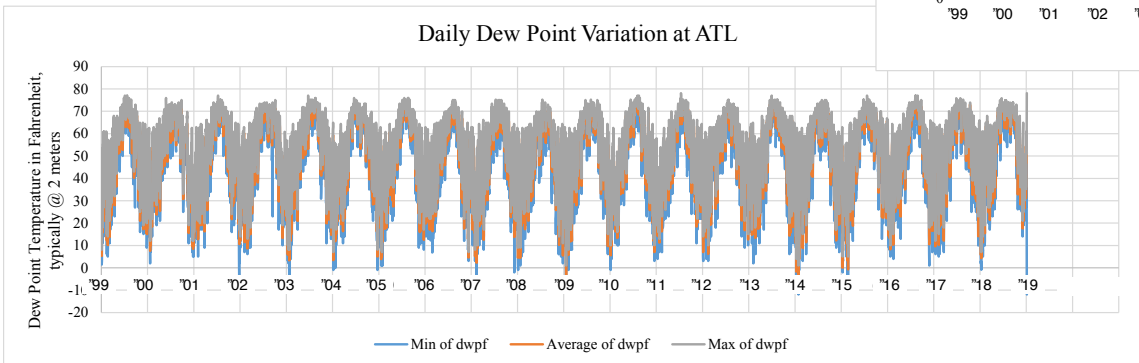
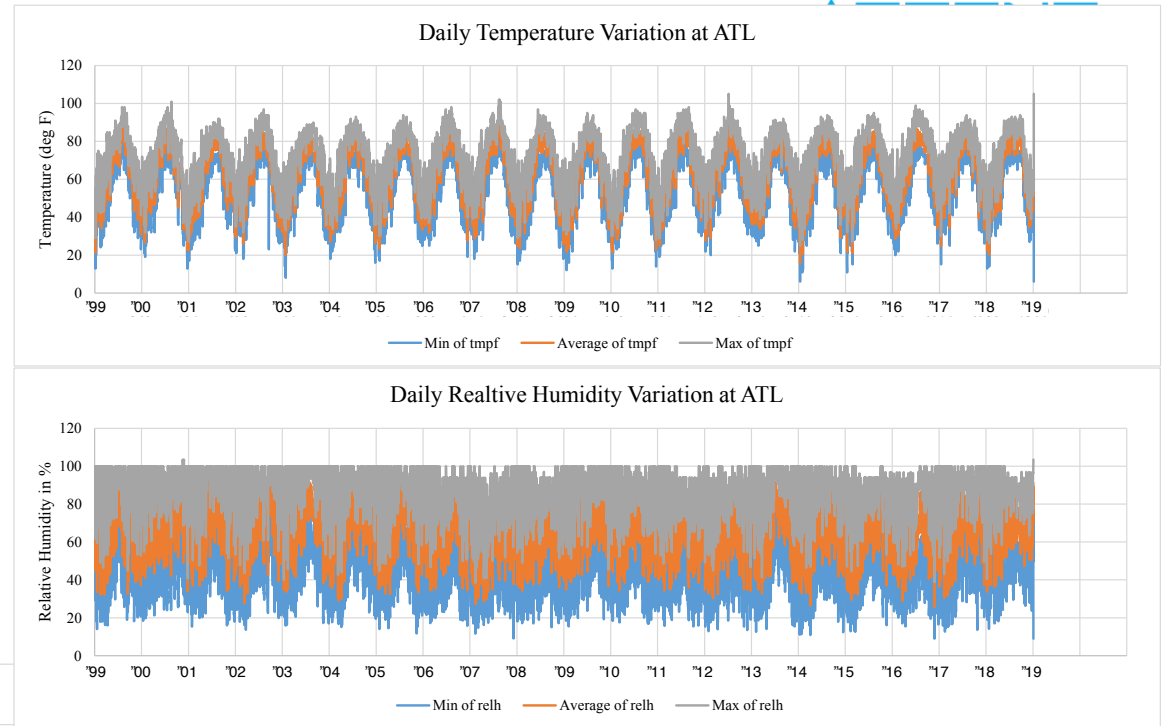
ASOS User's Guide has detailed information about these data variables. The value "M" represents either value that was reported as missing or a value that was set to missing after meeting some general quality control check, or a value that was never reported by the sensor. The METAR format makes it difficult to determine which of the three cases may have happened.

- station: three or four character site identifier
- valid: timestamp of the observation
- tmpf: Air Temperature in Fahrenheit, typically @ 2 meters
- dwpf: Dew Point Temperature in Fahrenheit, typically @ 2 meters
- relh: Relative Humidity in %
- drct: Wind Direction in degrees from north
- sknt: Wind Speed in knots
- p01: One hour precipitation for the period from the observation time to the time of the previous hourly precipitation reset. This varies slightly by site. Values are in inches. This value may or may not contain frozen precipitation melted by some device on the sensor or estimated by some other means. Unfortunately, we do not know of an authoritative database denoting which station has which sensor.
- alti: Pressure altimeter in inches
- mslp: Sea Level Pressure in millibar
- vsby: Visibility in miles
- gust: Wind Gust in knots
- skyc1: Sky Level 1 Coverage
- skyc2: Sky Level 2 Coverage
- skyc3: Sky Level 3 Coverage
- skyc4: Sky Level 4 Coverage
- skyl1: Sky Level 1 Altitude in feet
- skyl2: Sky Level 2 Altitude in feet
- skyl3: Sky Level 3 Altitude in feet
- skyl4: Sky Level 4 Altitude in feet
- wxcodes: Present Weather Codes (space separated)
- feel: Apparent Temperature (Wind Chill or Heat Index) in Fahrenheit
- ice_accretion_1hr: Ice Accretion over 1 Hour (inches)
- ice_accretion_3hr: Ice Accretion over 3 Hours (inches)
- ice_accretion_6hr: Ice Accretion over 6 Hours (inches)
- peak_wind_gust: Peak Wind Gust (from PK WND METAR remark) (knots)
- peak_wind_drct: Peak Wind Gust Direction (from PK WND METAR remark) (deg)
- peak_wind_time: Peak Wind Gust Time (from PK WND METAR remark)
- metar: unprocessed reported observation in METAR format



Historical Weather Data

- Utilize historical weather to determine the bounds for each parameter
- Execute a DoE to determine noise metric sensitivity to spectral/weather data



- Results will provide insight to the uncertainty in weather and noise propagation for Task 3
- Collaborate with PSU (Vic) to acquire 3D weather data from Spire Global for validation purposes

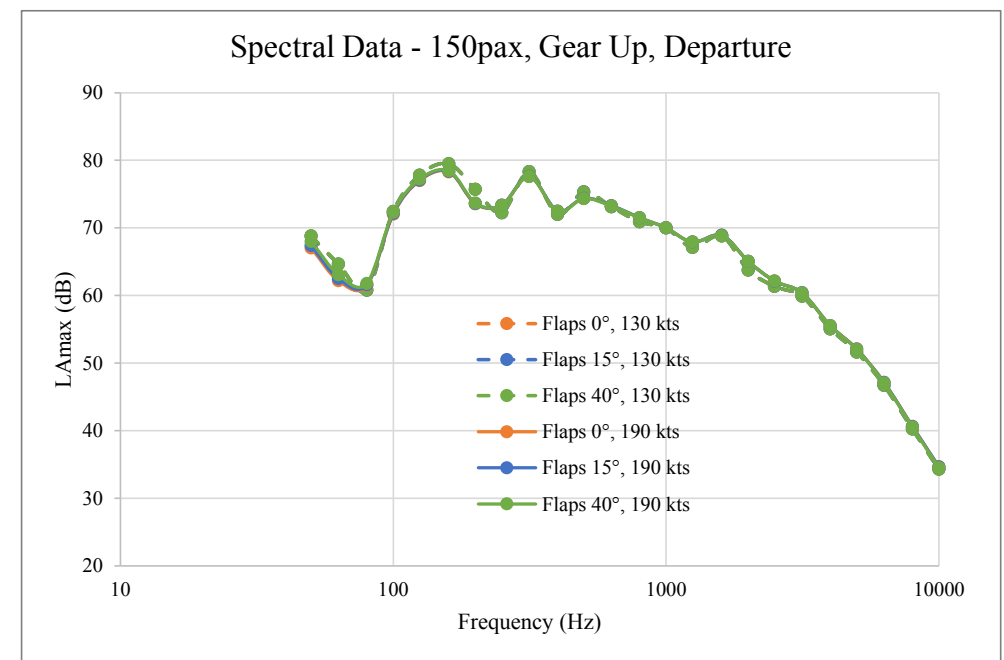
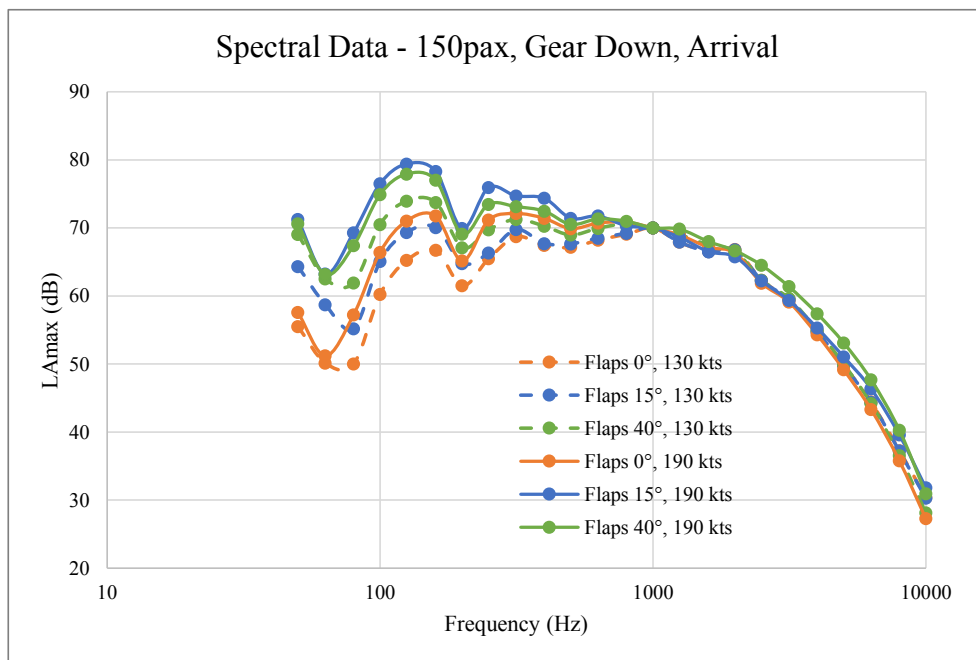
Task 2: Investigate Impact of Frequency Content on NPD+C



- New students are getting up to speed on EDS/ANOPP and the prior analysis conducted with the multiple NPDs
 - Repeating prior analysis to ensure consistency
 - Investigating the spectral data sensitivity to changes in speed and configuration
 - Developing automation scripts
- Another portion of the team is resurrecting the AEDT code modifications made $\sim 2+$ years ago to handle multiple NPDs so as to gain insight on how to modify it to handle multiple spectral data
 - Challenge: that working version of AEDT is out of sync with the current public release version AEDT3c
 - This is doable, it will just take a lot of code modifications
- Ideally, GT would like to hand over the code modifications maintenance to the AEDT development team

Initial Spectral Sensitivity

- Approach spectral data is much more sensitive to flap and speed settings, which will require modeling in AEDT
- As expected, little variation on departure since noise is dominated by the engine, which will not require modeling in AEDT



Task 3: Validation

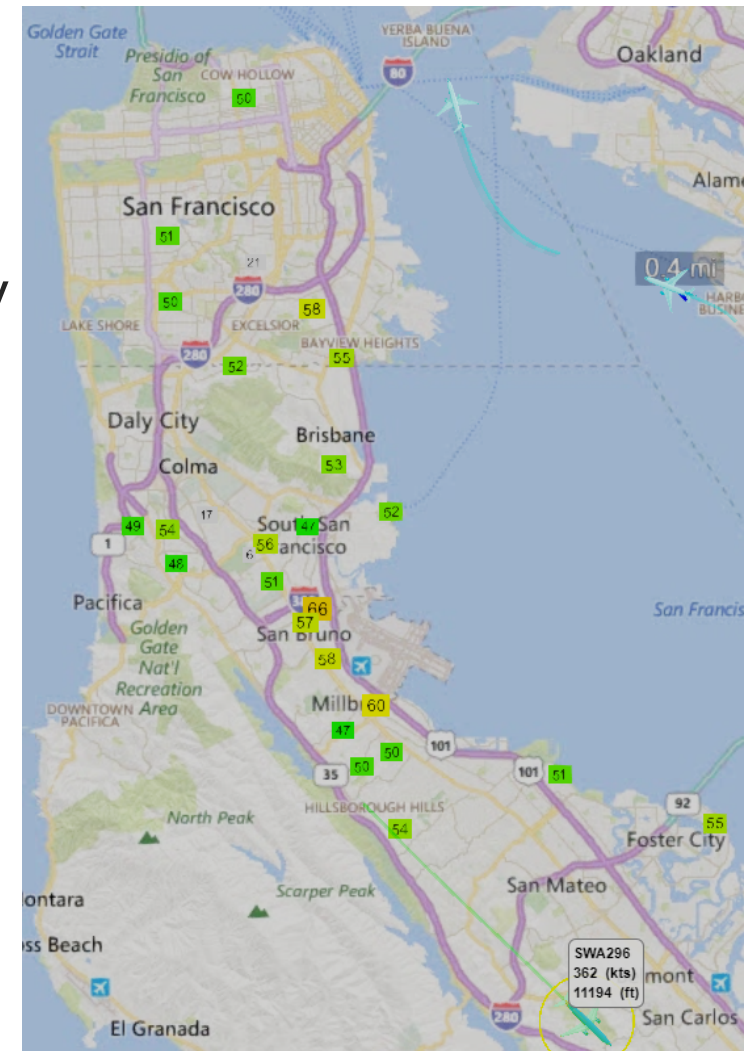


- Potential challenges in using measurement data for source noise validation
 - Uncertainties in aircraft state
 - Flap/slat setting
 - Thrust setting
 - Weight
 - Speed
 - Uncertainties in the atmospheric conditions
 - Humidity alone may cause a large variation in noise measurement
 - Wind speed/direction
 - Errors in noise propagation model
- How to overcome?
 - Use data from higher fidelity sources such as FOQA to reduce uncertainties in aircraft state (flap, thrust, weight etc.) and weather
 - Coordinate with the right individuals/companies to minimize the uncertainty

SFO Noise Monitor Data



- GT's ASCENT Project 45 team had a telephone interview with SFO's Bert Ganoung, Manager of Aircraft Noise Abatement Office
- The interview was mainly about the history of NADP usages at SFO
- SFO has a very successful "Fly Quiet" program launched in 2002
- As part of the program, SFO has been operating 30+ noise monitors around the airport
- It uses an ANEEM system that utilizes the radar data to map a sound recording to a flight
- SFO is willing to share the noise and the radar data with GT

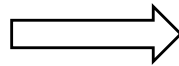


<https://www.flysfo.com/community/noise-abatement/fly-quiet>

Create A Fixed Point Profile Path Study Manually



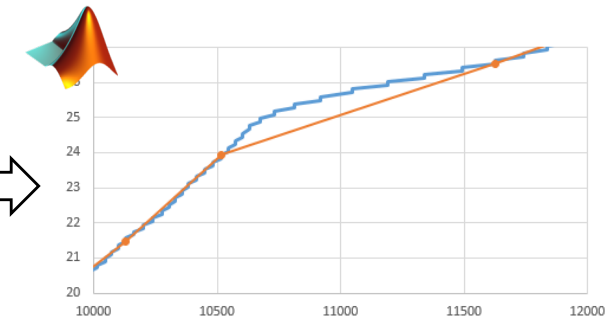
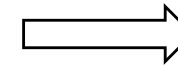
Aircraft FOQA data



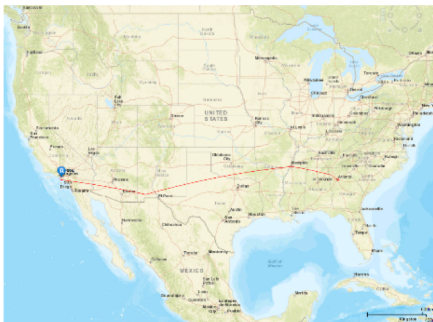
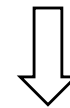
Real Flight Data (B767 from LAX to ATL) - 1801

Node	Phase	Time	Lon	Lat	Height	Altitude	Ground Speed
1	TAXI OUT	6:23:23	-118.38	33.9395	0	-120	11
2	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	10
3	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	10
4	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	10
5	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	9
6	TAXI OUT	6:23:23	-118.381	33.9395	0	-121	9
7	TAXI OUT	6:23:23	-118.381	33.9395	0	-121	9
8	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	8
9	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	8
10	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	7
11	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	7
12	TAXI OUT	6:23:23	-118.381	33.9395	0	-120	6
13	TAXI OUT	6:23:23	-118.381	33.9395	0	-119	5

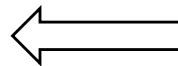
Parse Location and Speed data



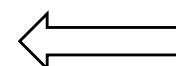
Sample profile points



Create study



AEDT import using SQL Scripts



	A	B	C	D	E	F	G	H	I	J
1	ACFT_ID	OP_TYPE	PROF_ID1	PROF_ID2	PT_NUM	DISTANCE	ALTITUDE	SPEED	THR_SET	OP_MODE
2	737800	D	FOQA_Dep_v1	6	1	0.000	0.000	5.357	328.335	D
3	737800	D	FOQA_Dep_v1	6	2	27.237	0.000	5.404	680.298	D
4	737800	D	FOQA_Dep_v1	6	3	54.788	0.003	5.487	1674.684	D
5	737800	D	FOQA_Dep_v1	6	4	86.591	0.003	7.074	3917.029	D
6	737800	D	FOQA_Dep_v1	6	5	99.397	0.008	8.100	4353.602	D
7	737800	D	FOQA_Dep_v1	6	6	113.930	0.008	9.121	8333.967	D
8	737800	D	FOQA_Dep_v1	6	7	131.867	0.287	12.133	14924.142	D
9	737800	D	FOQA_Dep_v1	6	8	156.143	0.287	16.634	18572.397	D
10	737800	D	FOQA_Dep_v1	6	9	188.431	0.647	21.627	20471.864	D
11	737800	D	FOQA_Dep_v1	6	10	229.145	0.647	26.618	21818.266	D
12	737800	D	FOQA_Dep_v1	6	11	278.282	1.043	31.607	22202.660	D
13	737800	D	FOQA_Dep_v1	6	12	335.411	1.043	36.090	22470.972	D
14	737800	D	FOQA_Dep_v1	6	13	555.991	1.937	51.040	22913.053	D
15	737800	D	FOQA_Dep_v1	6	14	851.078	2.448	65.521	22940.426	D

Create PROFILE_POINTS ANP Table

Initial modeling approach to test the process and will be automated to model and process more flights

Fixed Point Profile Method

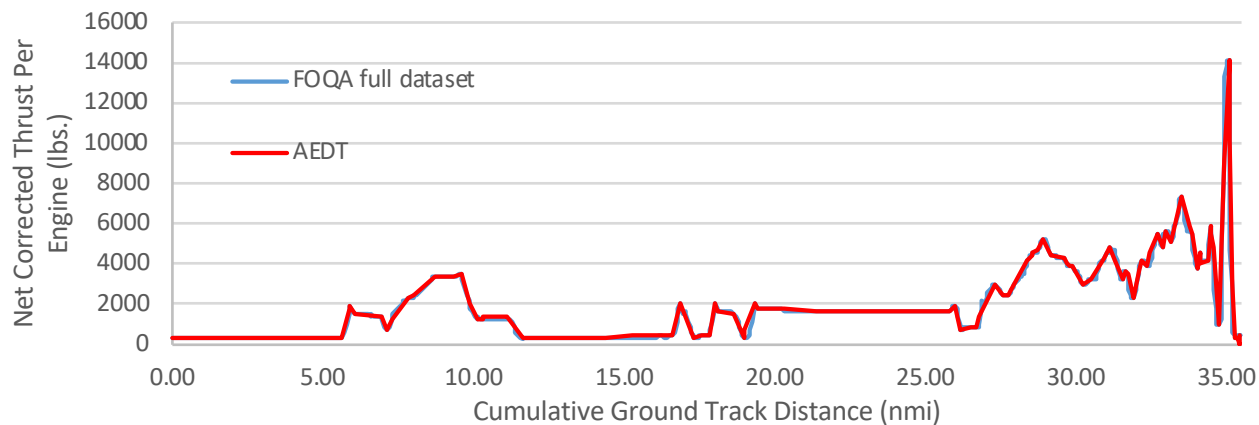
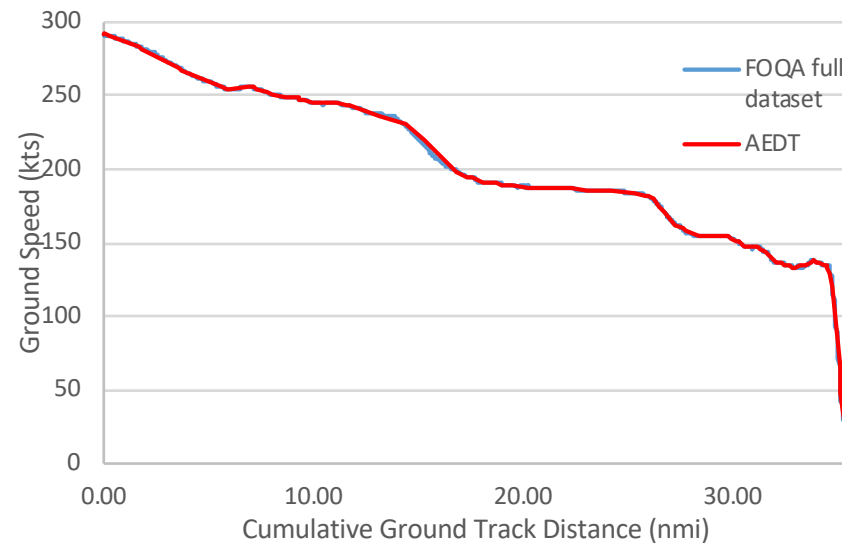
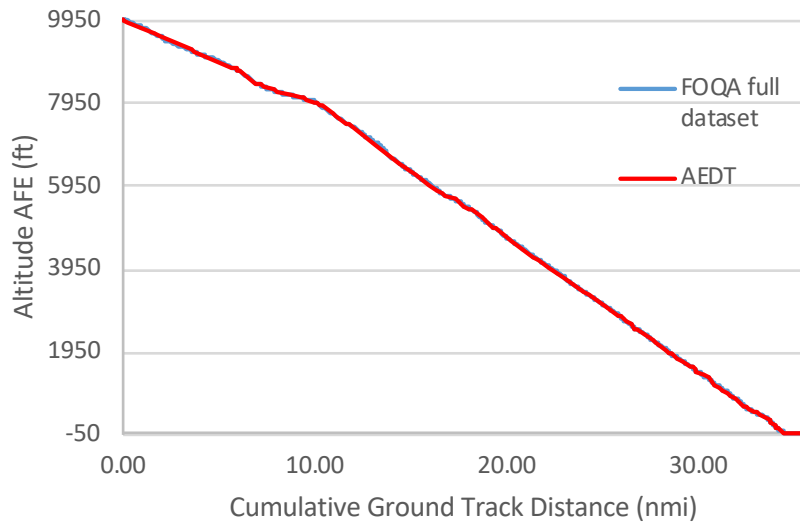


- The most straight forward way to model a FOQA flight is through AEDT's fixed point profile method
- Steps
 - Gather the entire flight data from FOQA
 - Filter to collect data at altitudes below 15,000ft AFE and remove taxing, maintaining key feature of trajectory
 - Automated script to select appropriate segment points to retain trajectory shape, thrust and speed trends, minimize sampling errors
 - Populate in SQL database
 - Create point ground track in AEDT GUI with lat-long data acquired from FOQA
 - Match created point profile to ground track when modeling in aircraft operations
- Comparison
 - Once fixed point profile outputs are obtained, compare with noise monitoring data for validation (ongoing)

Fixed Point Profile Modeling Example



Compare AEDT and original FOQA data to ensure reasonable agreement



Summary/Next Steps



Summary of current efforts under ASCENT 43 project are:

1. Spectral sensitivity

- Initiated modeling plan for sensitivity tests and developing scripts to automate the process
- Complete tests within the next few months

2. Spectral sensitivity with NPD+C

- Working on modifications to AEDT source code to handle multiple spectral data sets
- Once completed, the sensitivity analysis can begin

3. Validation with real world data

- Gathering and modeling airline FOQA data in AEDT
- Working with SFO on the noise monitoring data for the associated FOQA flights
- Initiating comparison of real world data to AEDT standard profile

Acknowledgements



- Bill He, Joe DiPardo, and Mohammed Majeed, FAA
- Juliet Page and Eric Boeker for invaluable insight into prior work
- Bert Ganoung Aircraft Noise Abatement Manager | Planning, Design, & Construction with SFO
- Mike Doty, NASA Langley

Publications

- "Investigation of Aircraft Configuration and Speed on Traditional Noise-Power-Distance Curves" –NOISE-CON 2019
- A-21 meeting in DC (June 12 – 13) – coordinate with industry and European efforts

Participants

- GT Research Staff:
 - Michelle Kirby, Chris Perullo, Tejas Puranik, Yongchang Li, Don Lim (now at Boeing)
- GT Students:
 - Ameya Behere, Seulki "Connor" Kim, Sarah Malak, Shilpa Ravoory, Andrew Van Zwieten, Max Fernandez