FAA CENTER OF EXCELLENCE FOR ALTERNATIVE JET FUELS & ENVIRONMENT

Noise Power Distance Re-evaluation

Project 43

Lead investigator: Dimitri Mavris (PI), Chris Perullo (Co-I), Michelle Kirby (Co-I)
Project manager: Hua (Bill) He (FAA)

October 22 & 23, 2019
Alexandria, VA

This research was funded by the U.S. Federal Aviation Administration Office of Environment and Energy through ASCENT, the FAA Center of Excellence for Alternative Jet Fuels and the Environment, project 43 through FAA Award Number 13-C-AJFE-GIT-048 under the supervision of Hua (Bill) He. Any opinions, findings, conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the FAA.

ASCENT
AVIATION SUSTAINABILITY CENTER

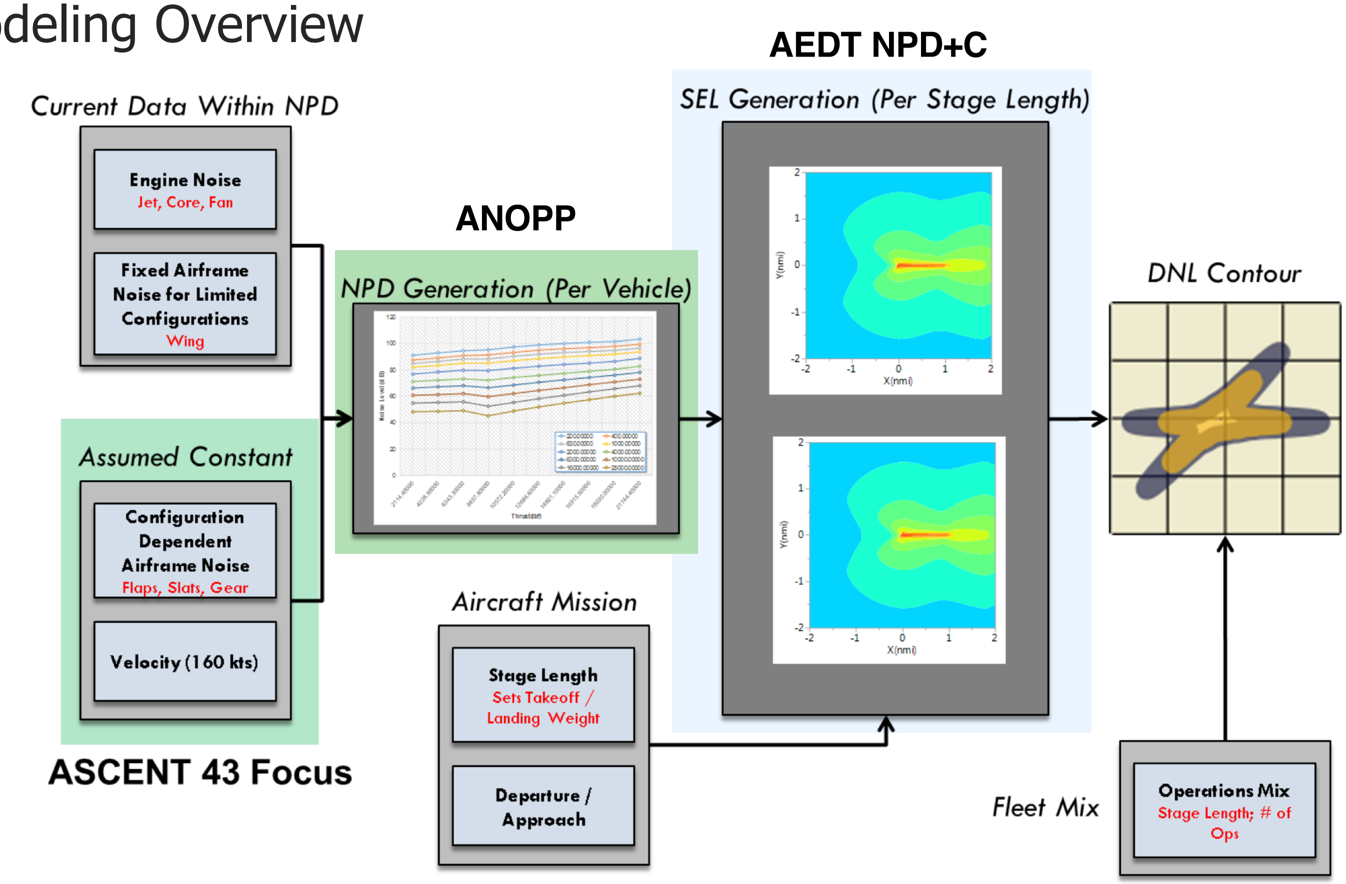
Project 43 Goals

- 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)

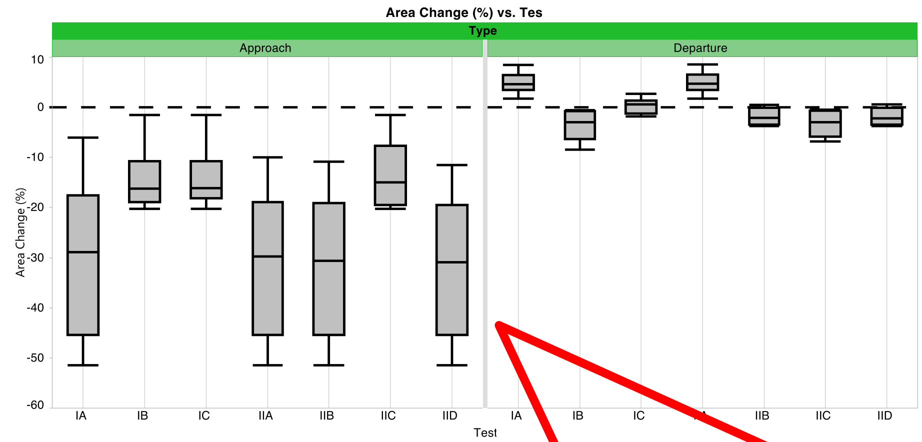
- Objectives
  - Understand the sensitivity of including aircraft configuration changes and reference speed in NPDs on resulting noise contours for 50 – 400 PAX
  - Provide physics-based recommendations on format of NPD + Configuration (NPD+C) curves for use in AEDT
  - Maintain compatibility as much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

- NPD Modeling Overview

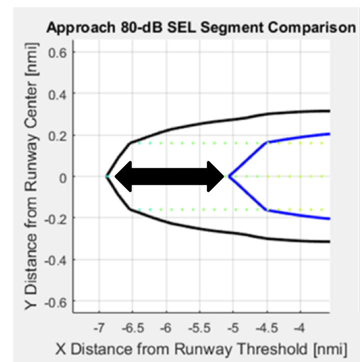


Summary of Key Findings

- 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. mfgrs)	Eurocontrol	• From manufacturers. • Considered to be well validated.	• 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	• The process is easy to understand • Consistent method for generating NPD+C	• 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)	• Able to create NPD+C sets from simpler inputs (available within AEDT). • No need to create ANOPP models for each a/c type.	• 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

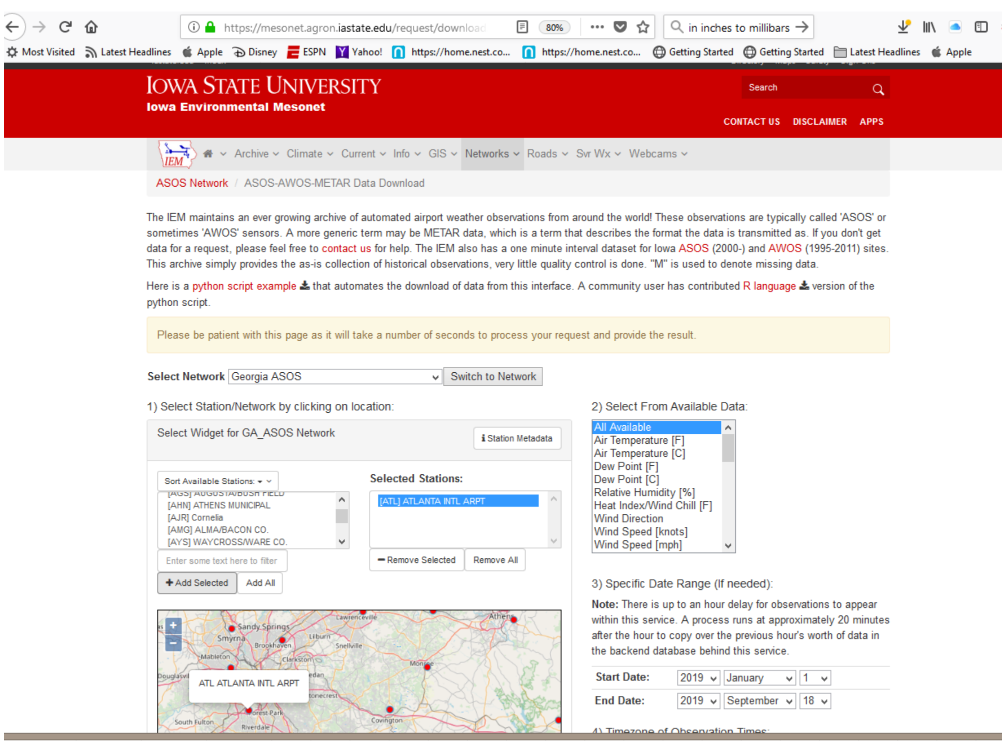
- Environmental impacts
  - Noise (SEL, LAmax, EPNL, PNLmax), emissions (NOx), and fuel consumption
- Weather parameters
  - Temperature, sea-level and station pressure, dew point, relative humidity, and wind speed (and cloudiness)
- Airports
  - SFO, ATL, DEN, and MEX
- Aircraft
  - CRJ900
  - B737-800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

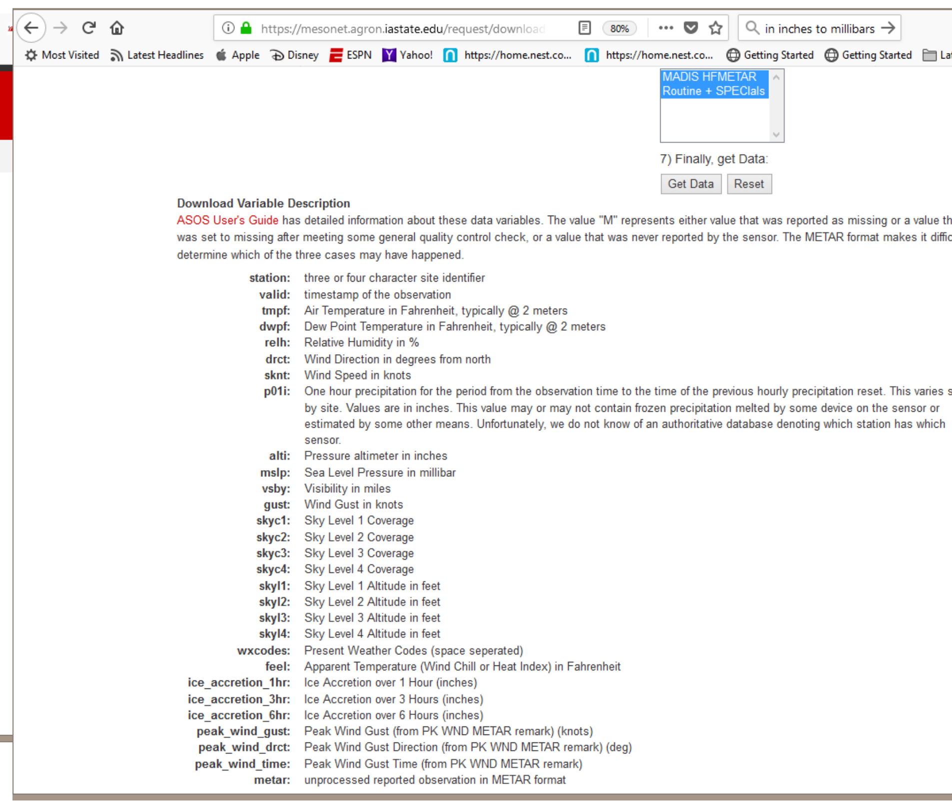
Weather Sources Example

- Weather sources

  Iowa State University Environmental Mesonet (https://mesonet.agron.iastate.edu/request/download.phtml?network=GA_ASOS)

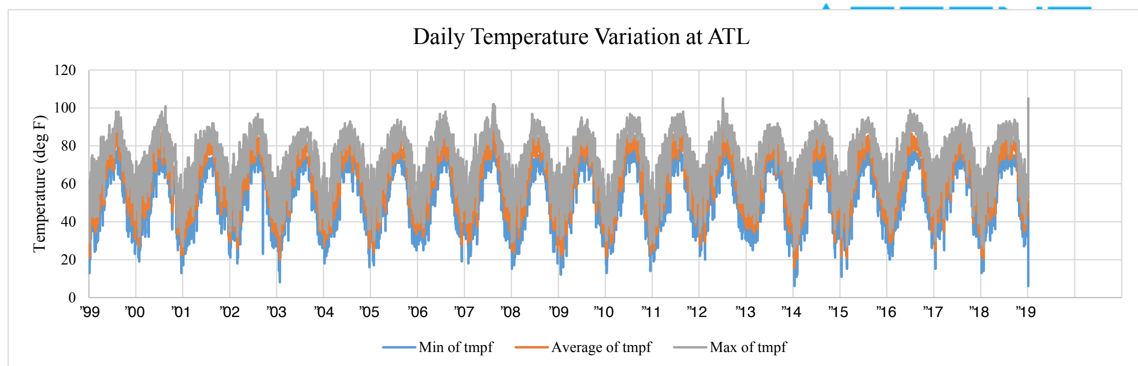
  – Weather data can be downloaded as CSV
  – Daily weather data back to 1928 – needs some processing

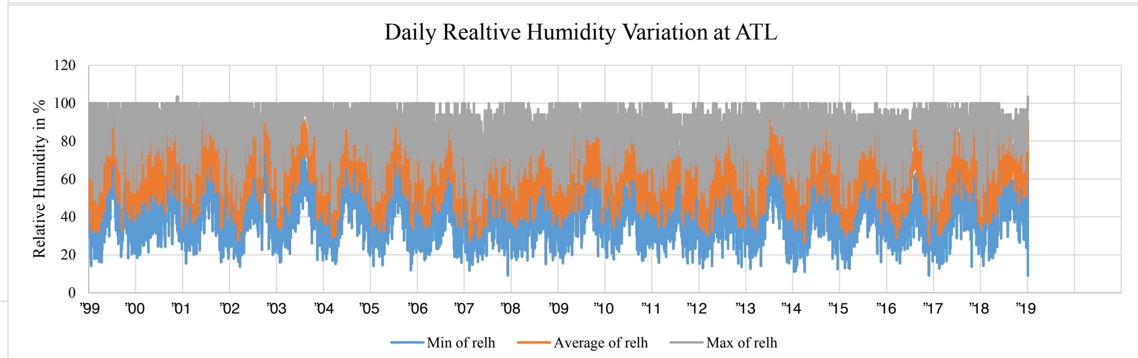


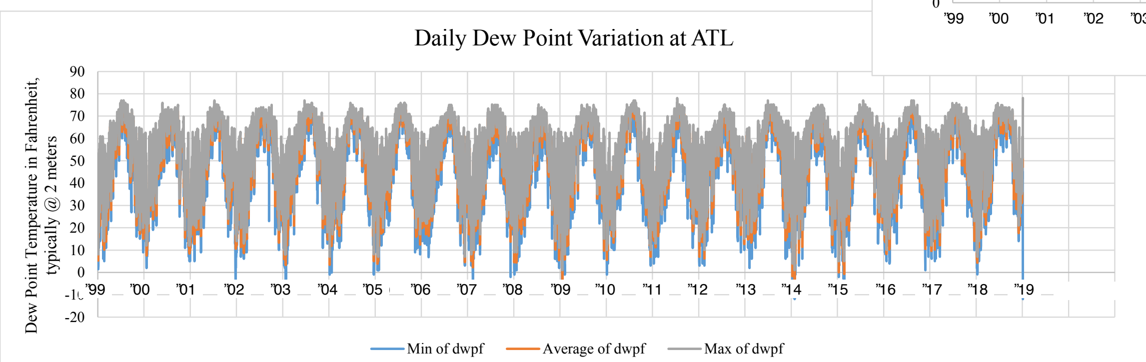


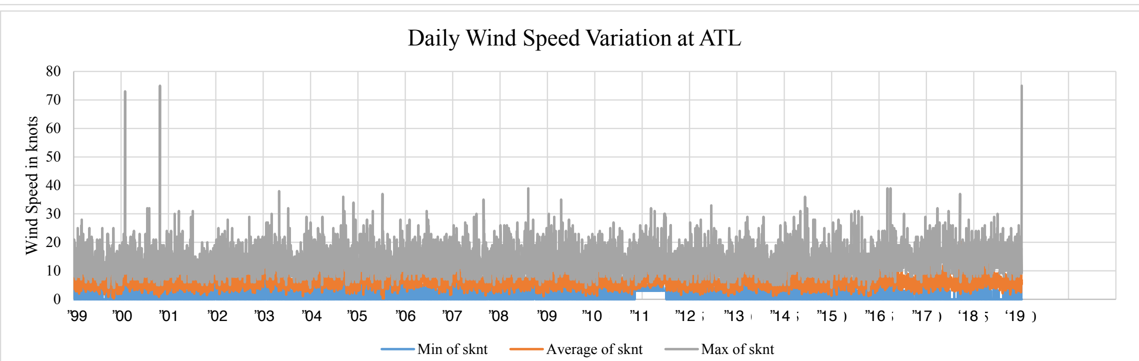
Historical Weather Data

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









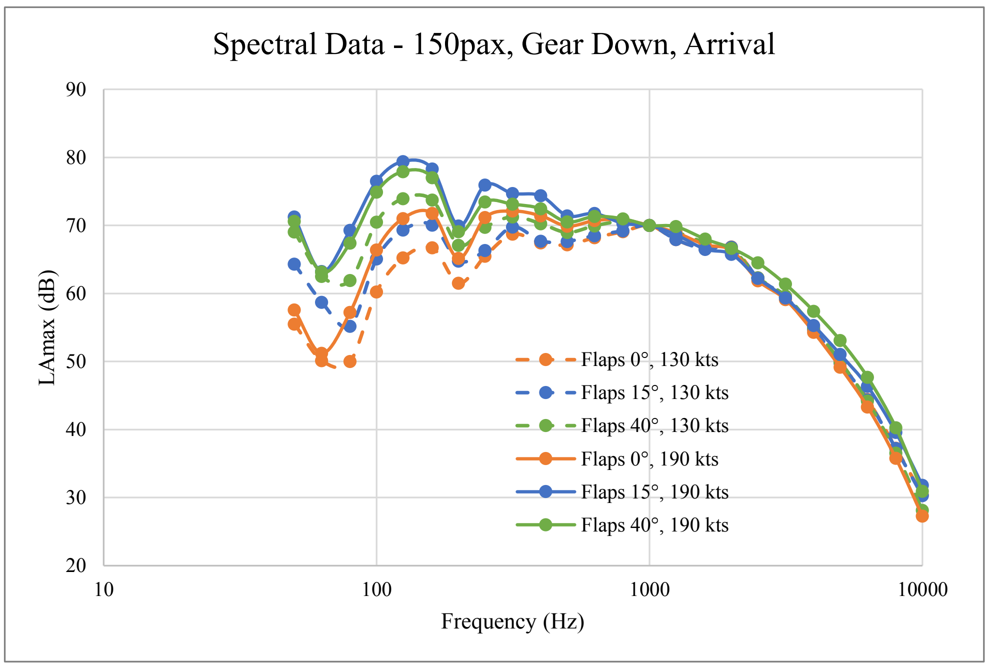
- Results will provide insight to the uncertainty in weather and noise propagation for Task 3
- Collaborate with PSU (Vic) to acquire 3D weather data from Spire Global for validation purposes

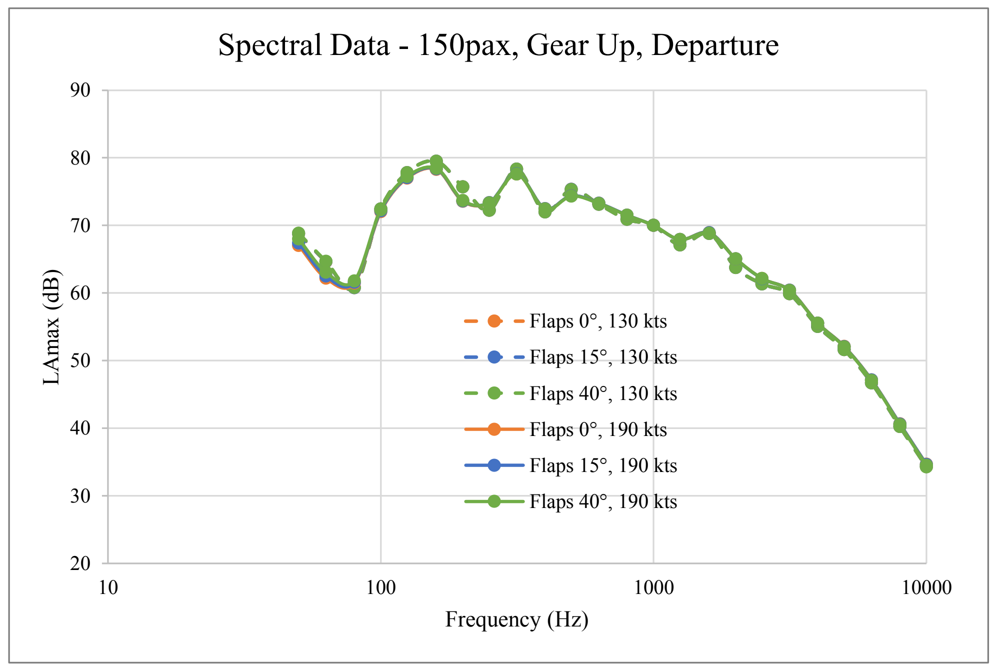
Task 2: Investigate Impact of Frequency Content on NPD+C

- 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 ~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



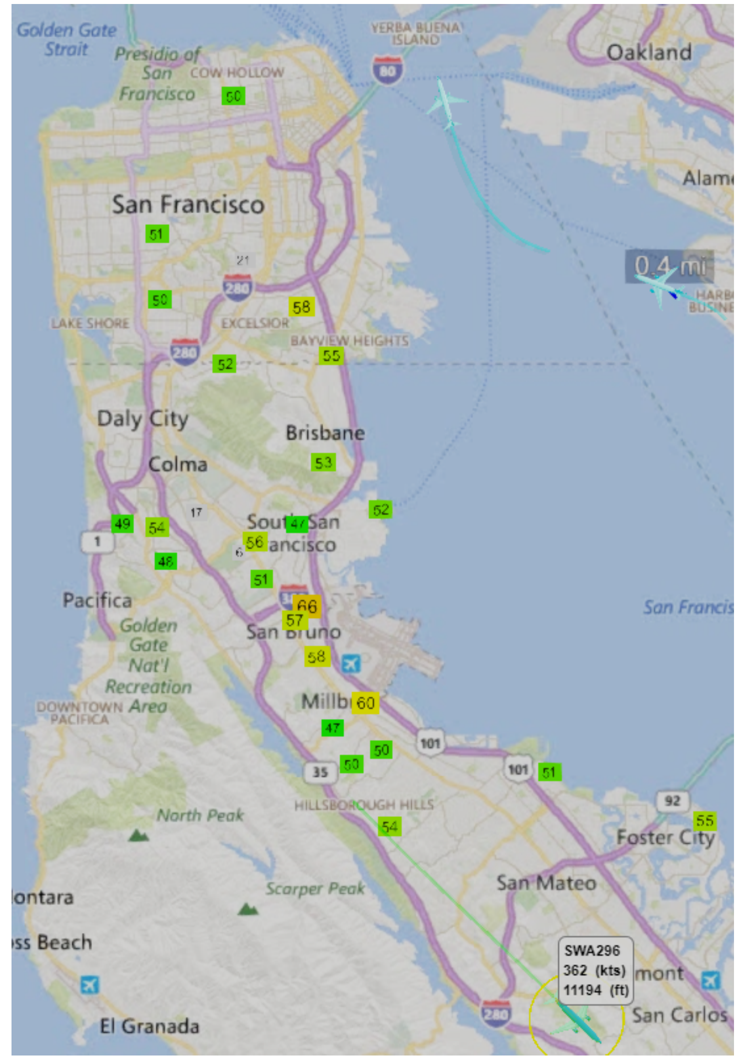


Task 3: Validation

- 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



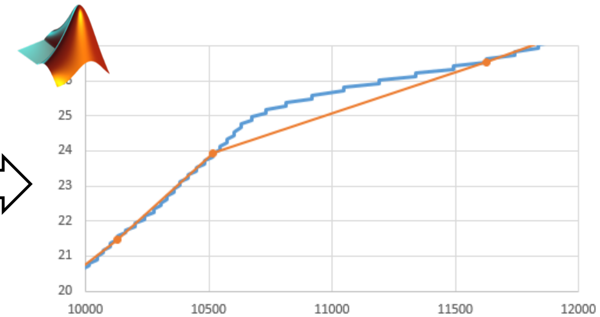
https://www.flysfo.com/community/noise-abatement/fly-quiet

Create A Fixed Point Profile Path Study Manually

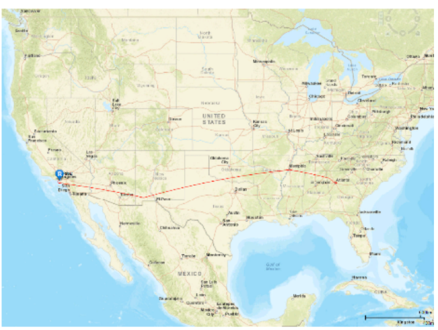
Aircraft FOQA data

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

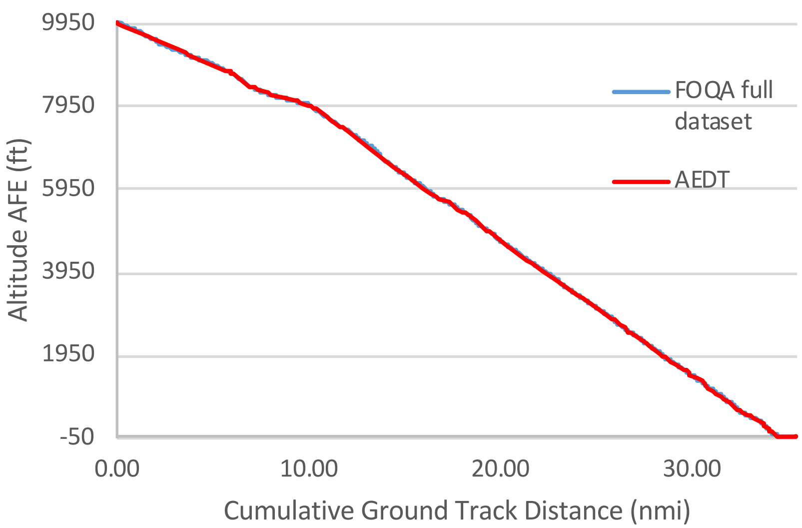
Initial modeling approach to test the process and will be automated to model and process more flights

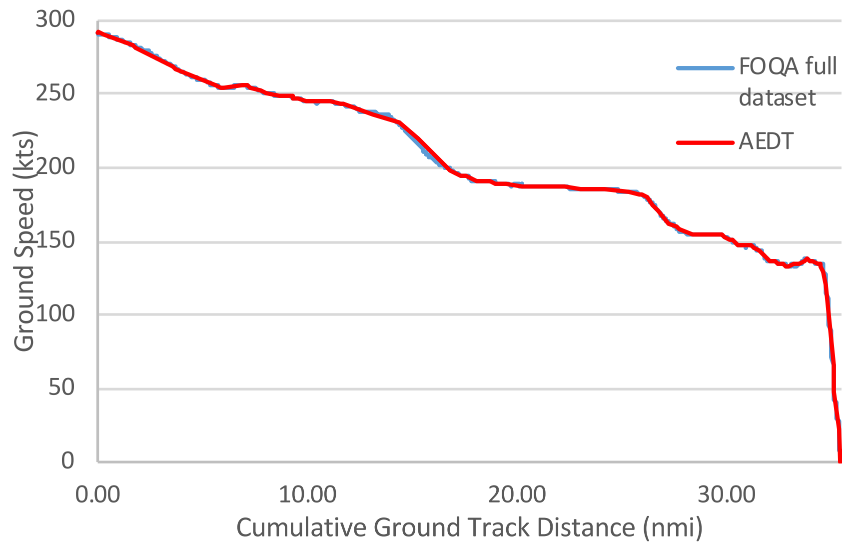
Fixed Point Profile Method

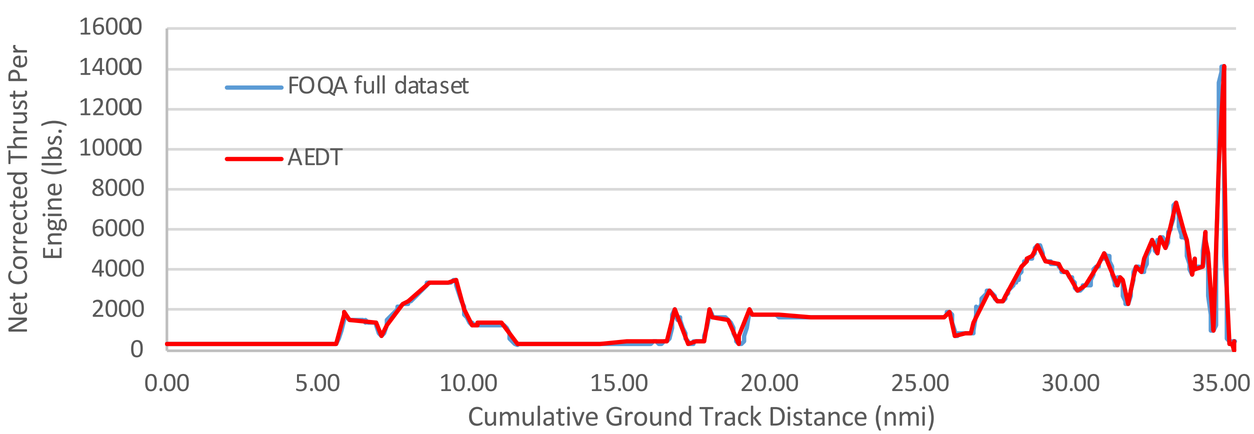
- The most straight forward way to model a FOQA flight is through AEDT's fixed point profile method
- Steps
  - Gather the entire flight data from FOQA
  - Filter to collect data at altitudes below 15,000ft AFE and remove taxing, maintaining key feature of trajectory
    - Automated script to select 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