Investigation of Speed and Altitude Effects on Sound Exposure Level Calculations for Multiple Helicopters

Mary Houston, Kyle Pascioni, James Stephenson

NASA Langley Research Center

186th Meeting of the Acoustical Society of America/

Acoustics Week in Canada

16 May 2024

Mary Houston: Mary.L.Houston@NASA.gov

Motivation

- A-Weighted Sound Exposure Level (L_{AE}) is an important metric for evaluating both loudness and duration of a single event[1,2]
- Scaling laws are sought to normalize data and compare flyovers at different reference altitudes or deviation from a reference altitude
- Ongoing effort of Fly Neighborly Committee[3] to identify minimum-noise cruising flight speeds, among other factors
- Generalizable guidance, scaling relationships and “rules of thumb” are desirable

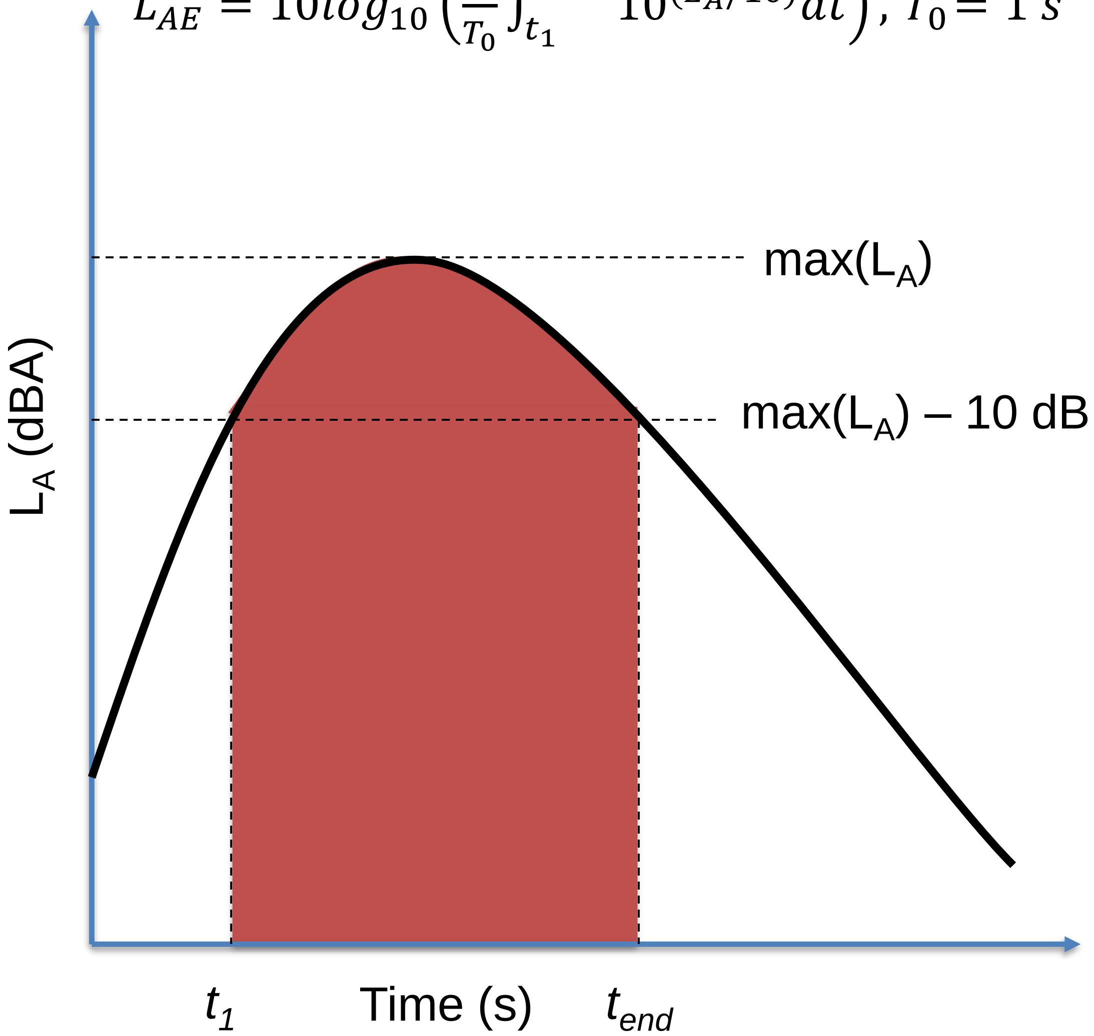
1. FAA, FAR Part 36, App. J, 2023
2. EASA, Guidelines on Noise Measurement of Unmanned Aircraft Systems, 2023
3. Helicopter Association International – https://rotor.org/fly-neighborly

A-Weighted Sound Exposure Level

- L_{AE} is a noise metric accounting for both volume of the sound and its duration

- Integrate A-weighted sound pressure level (L_A) across time starting and stopping when the signal is within 10 dB of the peak

$$L_{AE} = 10log_{10}\left(\frac{1}{T_0}\int_{t_1}^{t_{end}} 10^{(L_A/10)}dt\right), T_0 = 1\ s$$



Airspeed Effect

- Slower is quieter (in general) for any instant in time
- Longer period of time vehicle is perceived by observer
- Example correction for off-reference airspeed[1]

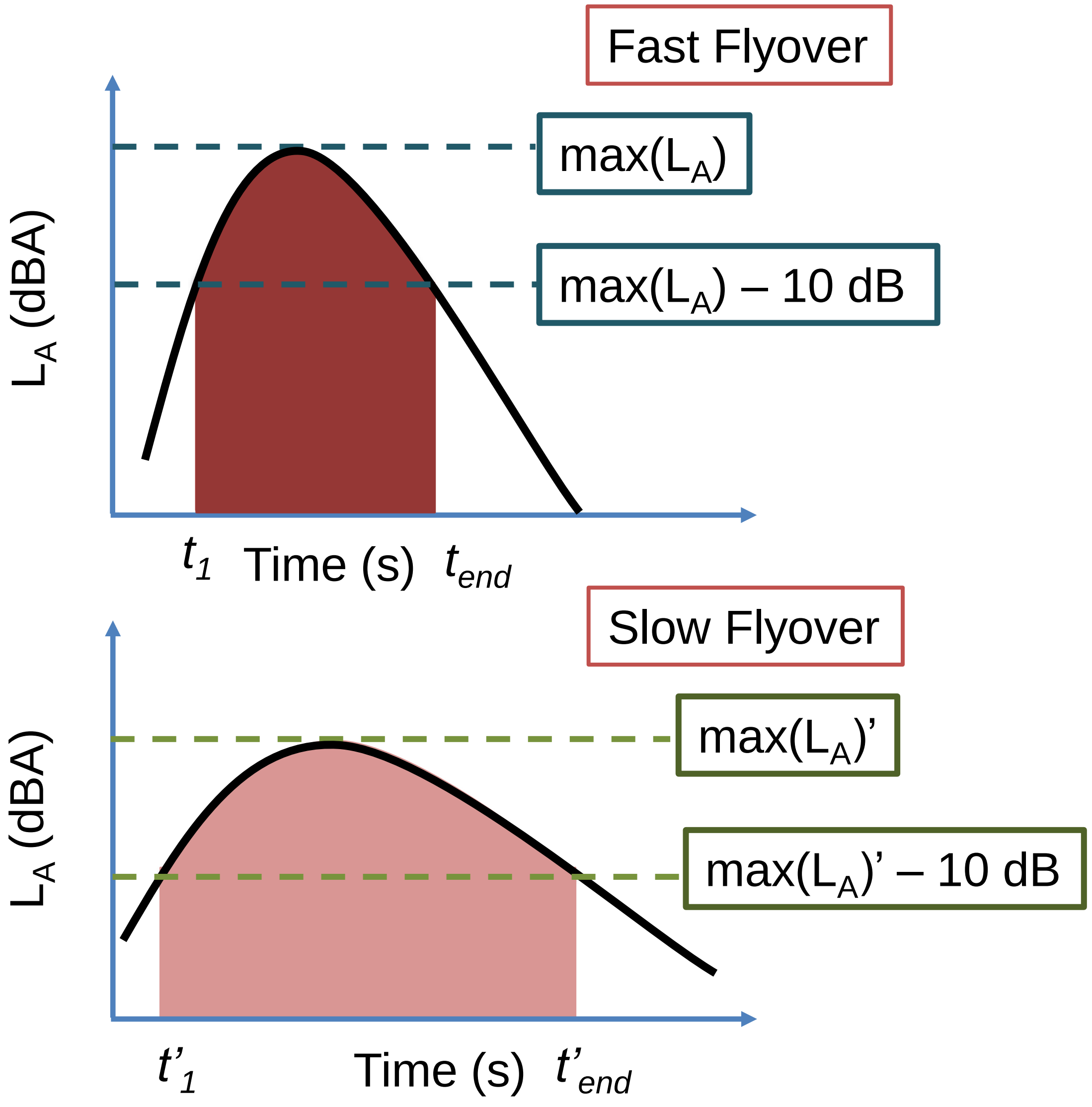
$$\Delta J_1 = 10log_{10}\left({}^{V_{RA}}/_{V_R}\right)\ \mathrm{dB}$$

ΔJ_1: Quantity to add to L_{AE} to account for deviation from reference airspeed

V_R: Reference airspeed

V_{RA}: Adjusted reference airspeed

- Accounts for duration effects → Slower is louder?
- Does not consider changes in noise mechanism with changing airspeed



Altitude Effect

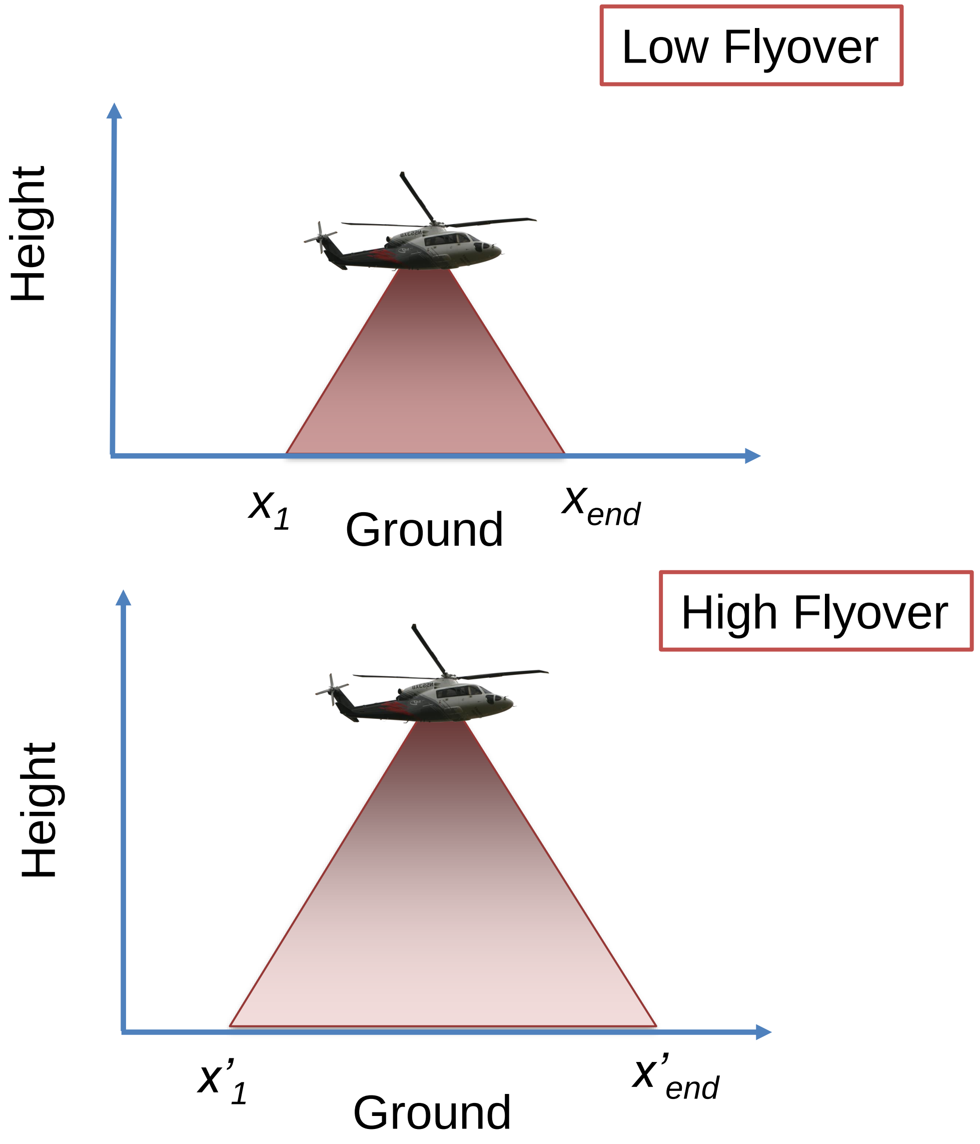
- Increasing altitude increases attenuation from spherical spreading and atmospheric absorption
- Vehicle is perceived by observer for longer duration
- Example correction for altitude[1]

$$\Delta J_3 = m * 10log_{10}\left(\frac{H_T}{H_R}\right) \text{dB}$$

m: Scaling factor accounting for spherical spreading and duration effects. Given as *m = 1.25*

H_T: Altitude of the test helicopter above ground level

H_R: Reference altitude. Given as *492 ft*



Method – Vehicles

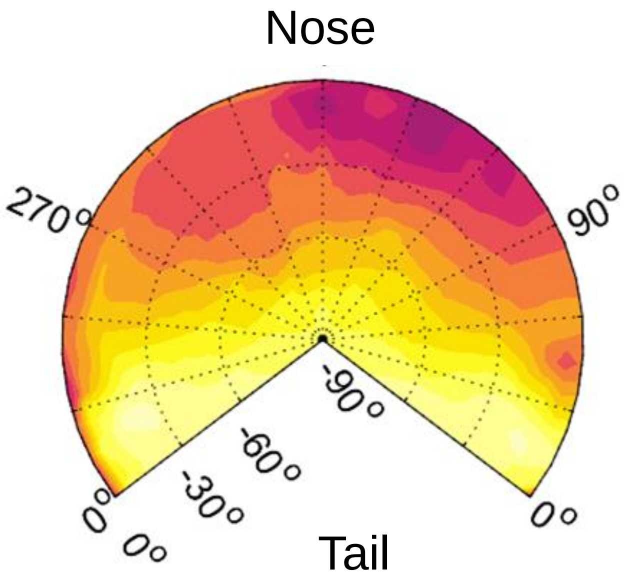
Selected level flyover data from

- Six light helicopters[4] (below)
- Four medium-sized helicopters[5] (right)

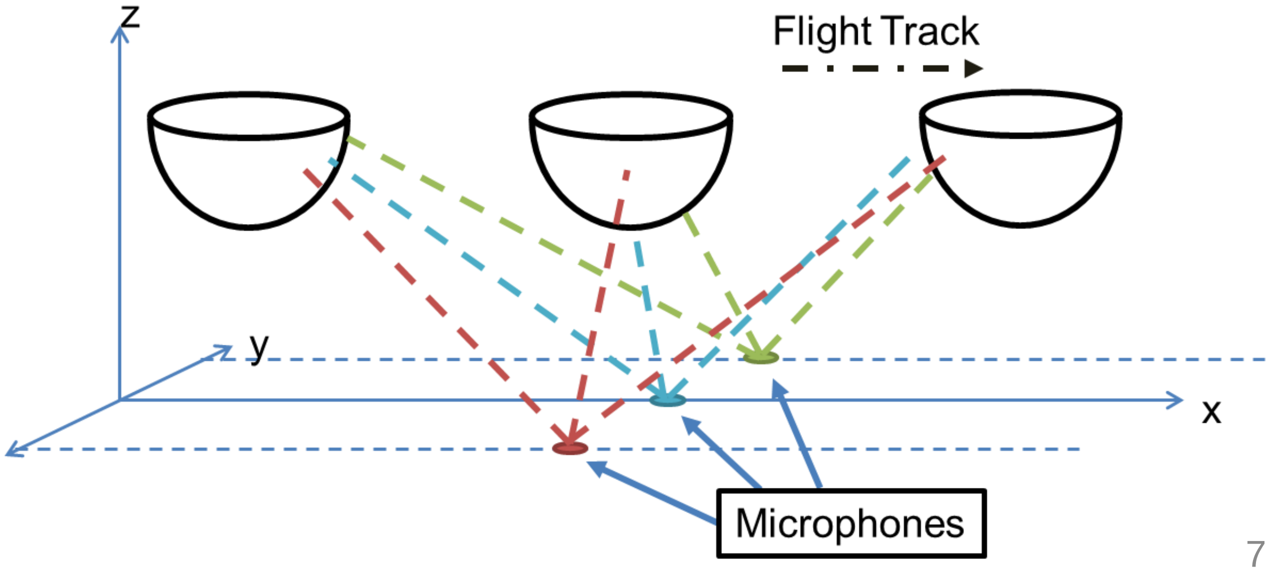
4. Watts 2019, 5. Pascioni 2021

Method – Virtual Flights

- Experimental Data Set
  - Large data set in form of rotorcraft noise hemispheres
  - Steady speed level flyovers at range of speeds
  - All helicopters had been flown at 40, 60, 80 and 100 knots airspeed

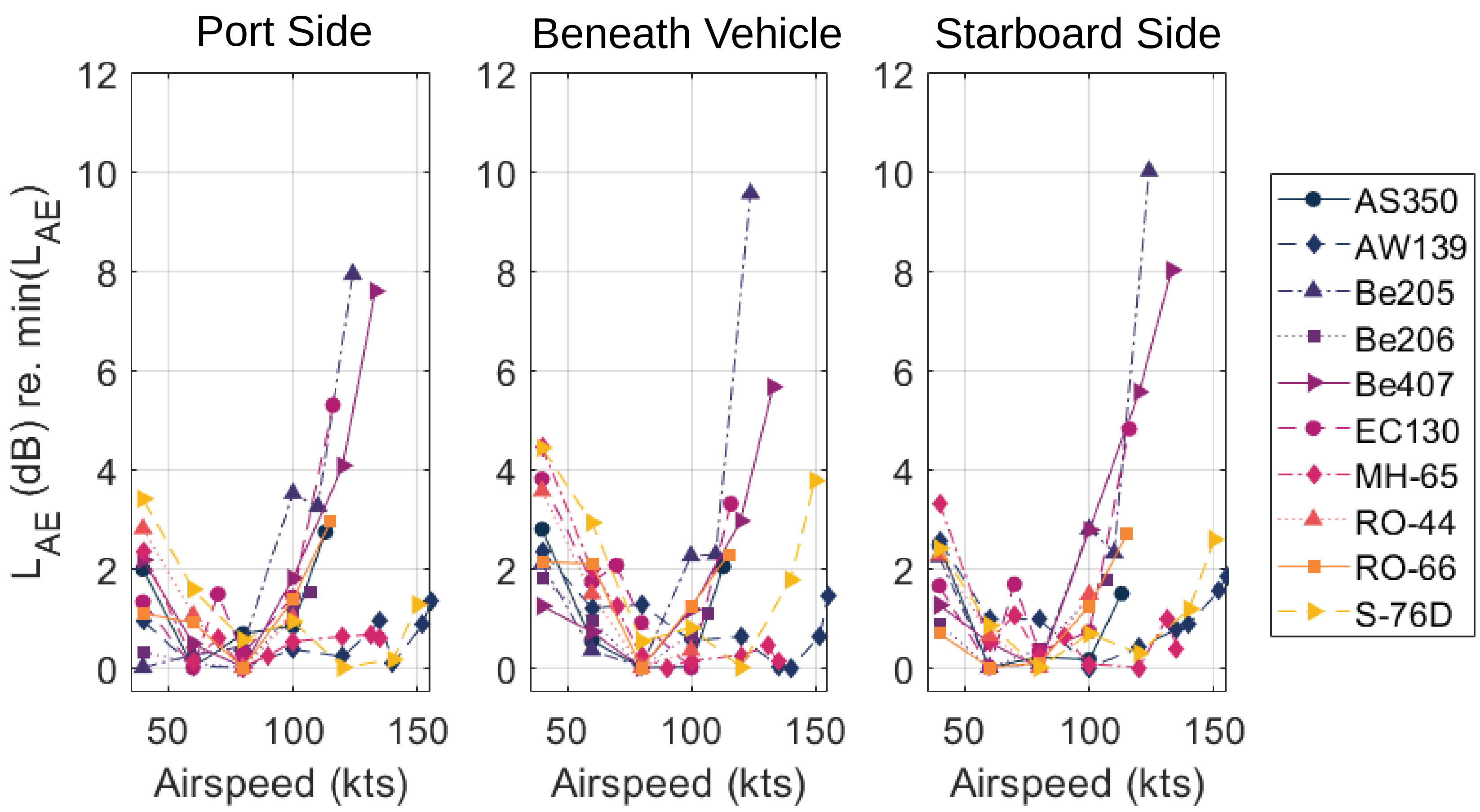


- Application of Data Set
  - Hemispheres virtually flown using the Advanced Acoustic Model (AAM)[6]
  - Altitudes of 200, 400, 500, 800 and 1600 ft
  - Calculate metrics (L_A, L_{AE}) beneath the flight track and at 45° from the flight track



6. Advanced Acoustic Model, 2020

Results – Airspeed

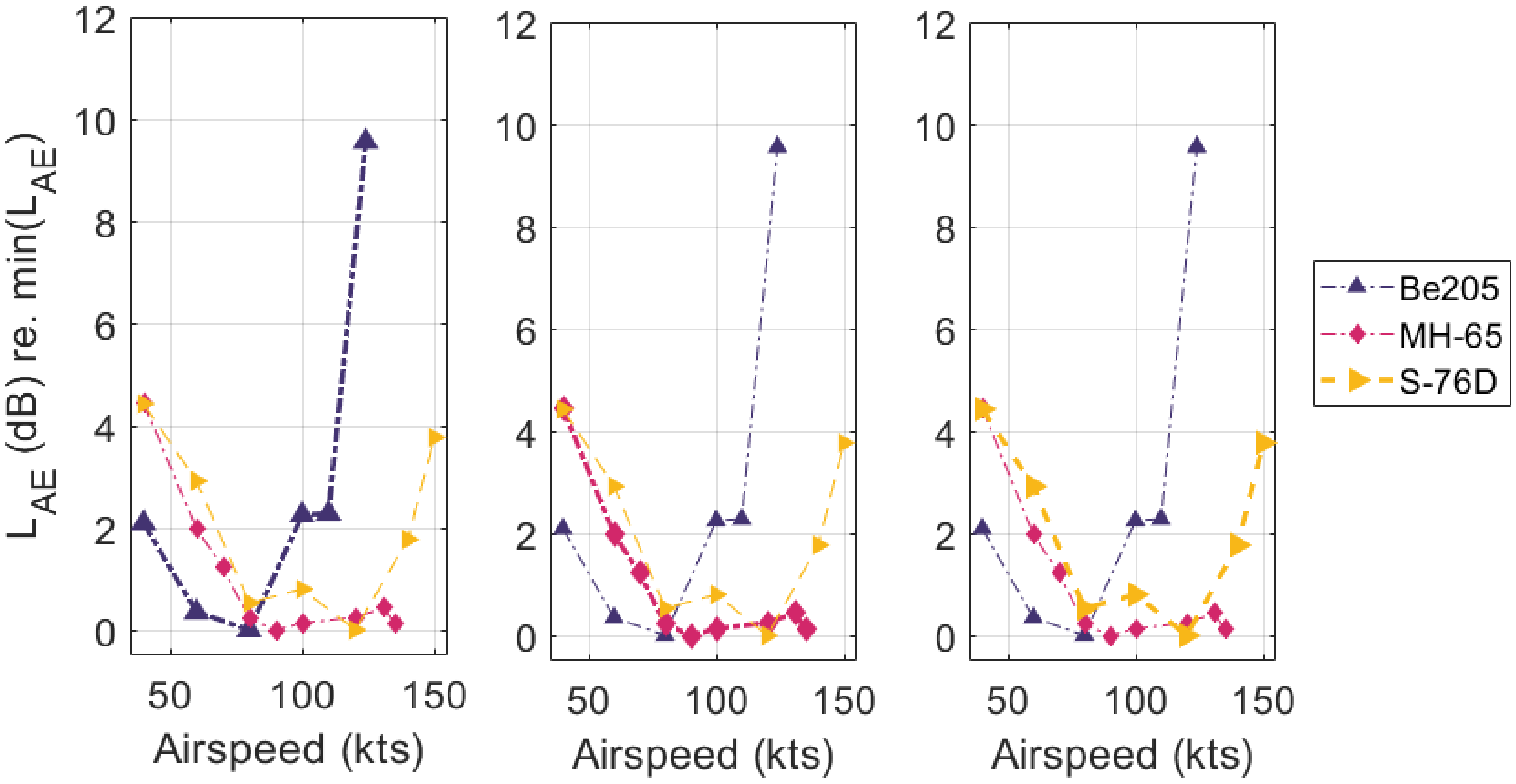


Airspeed that minimizes L_{AE} varies between aircraft

General trend of decreasing and increasing L_{AE} with increasing airspeed

Sounds levels beneath, and at 45° from, vehicle flight track at 500 ft altitude,
Relative to minimum value for each vehicle

Results – Airspeed



Sounds levels beneath vehicle flight track for 500 ft altitude, Relative to minimum value for each vehicle

Bell 205

- Minor decrease then significant increase in L_{AE} with increasing airspeed
- min(L_{AE}) at 80 kts

MH-65

- Significant decrease then near-constant L_{AE} with increasing airspeed
- min(L_{AE}) at 80 kts and above

S-76D

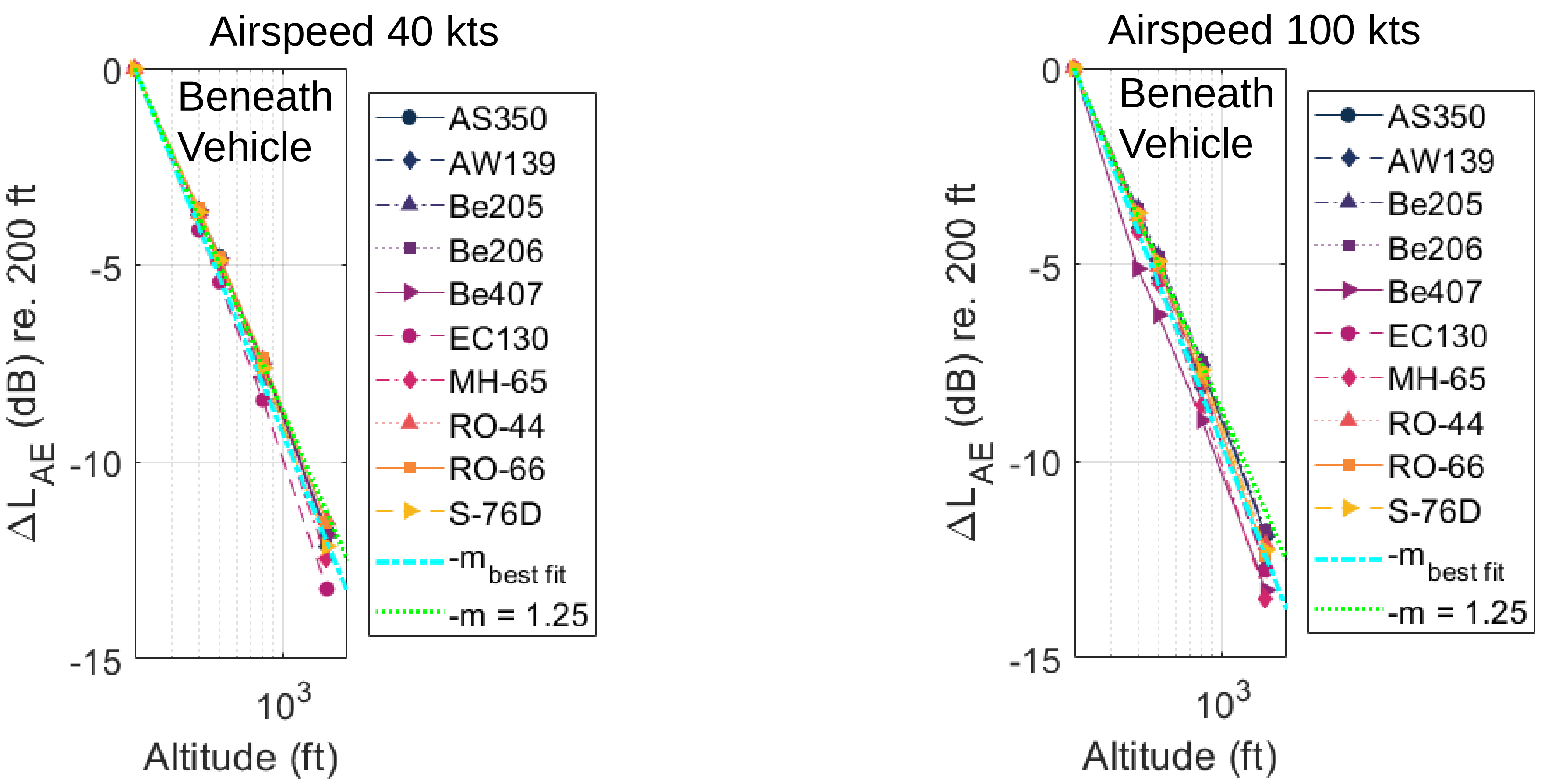
- Initial decrease followed by nearly equivalent increase in L_{AE} with increasing airspeed
- min(L_{AE}) at 120 kts

Results – Altitude

$$\Delta J_3 = m * 10log_{10}\left(\frac{H_T}{H_R}\right)\ \text{dBA}^1$$

Sounds levels along vehicle flight line at 200, 400, 500, 800 and 1600 ft altitude

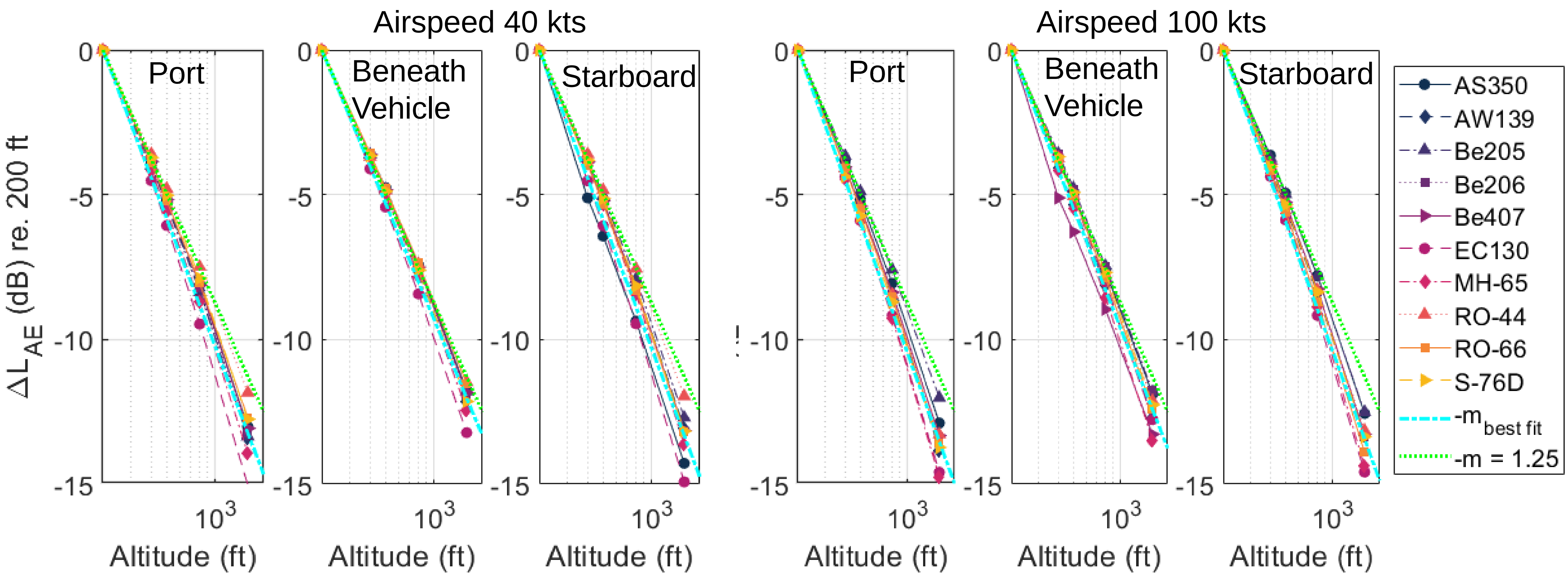
Levels relative to L_{AE} at 200 ft



Source: NASA

Results – Altitude

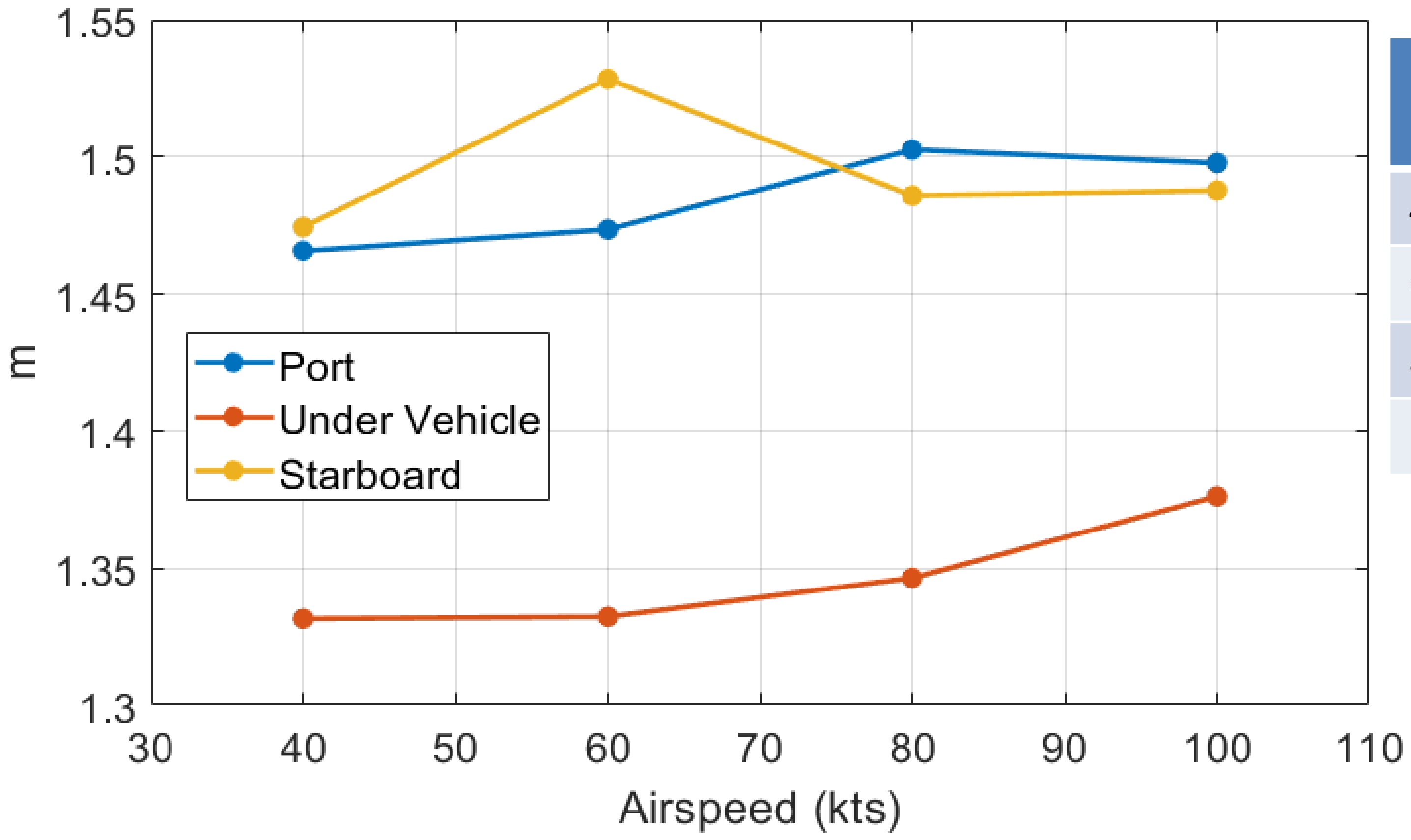
$$\Delta J_3 = m * 10log_{10}\left(\frac{H}{H_{ref}}\right) \text{dBA}^1$$



Sounds levels beneath, and at 45° from, vehicle flight track. Relative to 200 ft.

Results – Combined Effects

L_{AE} altitude scaling (*m*) factor at different airspeeds



	Port	Under Vehicle	Starboard
40 kts	1.47	1.33	1.47
60 kts	1.47	1.33	1.53
80 kts	1.50	1.35	1.49
100 kts	1.50	1.38	1.49

- Altitude scaling is relatively constant with airspeed
- Off flight line microphones are further from source and experience more attenuation

Conclusions

- Airspeed
  - Slower is not always quieter
  - Different vehicles have different lowest SEL speeds
- Altitude
  - Increased attenuation from spreading and atmospheric absorption with increased altitude
  - Not balanced by increased exposure time
  - Flying higher is always quieter
- Combined Effects:
  - Altitude scaling is relatively constant with airspeed

Altitude adjustment factor needs reevaluating to include absorption effects

References

1. Federal Aviation Regulations, F. A. R. (2023). Part 36: Noise Standards: Aircraft Type and Airworthiness Certification. Appendix J. *Washington, DC: US Federal Aviation Administration*.
2. European Union Aviation Safety Agency, Guidelines on Noise Measurement of Unmanned Aircraft Systems, 2023
3. Helicopter Association International, Fly Neighborly. https://rotor.org/fly-neighborly/
4. Watts, M., Greenwood, E., Smith, C., Stephenson, J. Noise Abatement Flight Test Data Report. NASA TM 220264. 2019
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Acknowledgements

The Authors would like to acknowledge Hua (Bill) He and Rick Riley of the Federal Aviation Administration for providing the suggestion for this research topic

This work was supported by the NASA Aeronautics Research Mission Directorate RVLT Project, as well as The United States Army DEVCOM Aviation & Missile Center