

# Progress in Aircraft Noise Prediction – Flight-Noise

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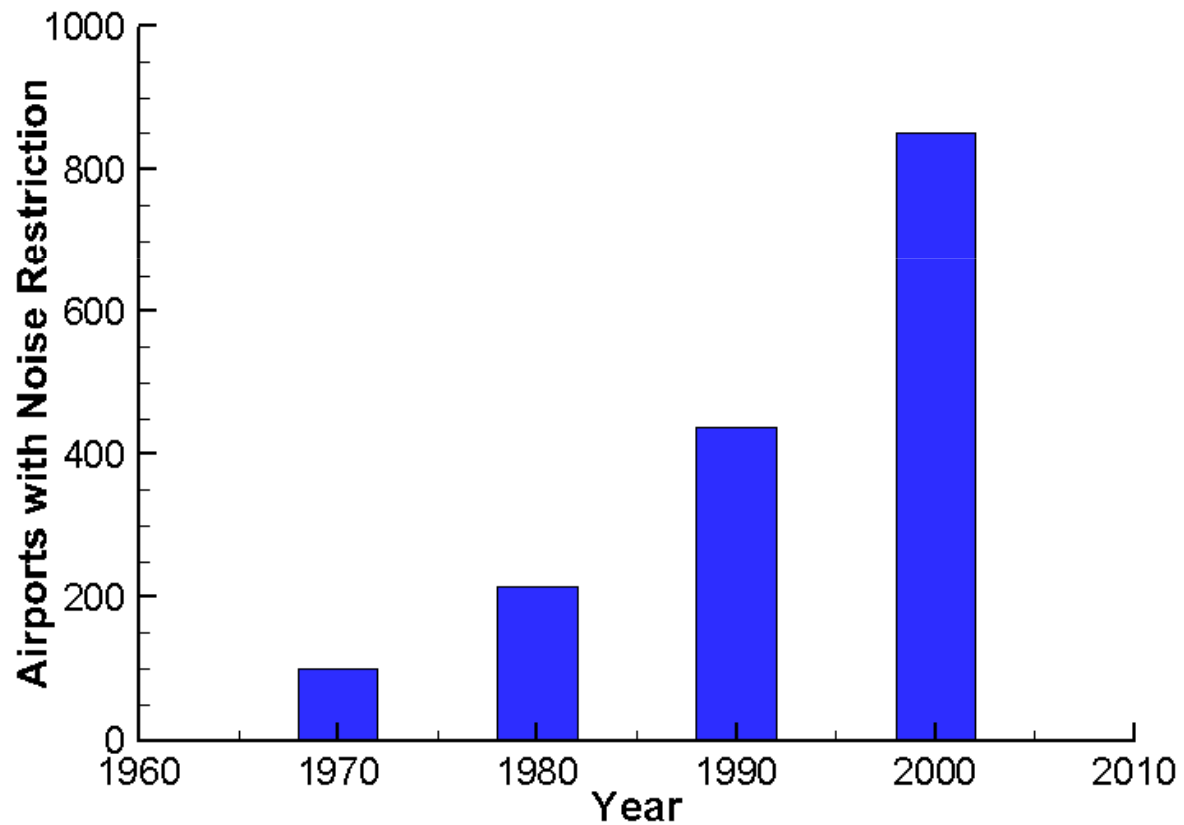
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# Aircraft Noise /2

- Certification Requirements (ICAO Stage 4)
- Essential in Flight Performance
- Land Planning, noise zoning, flight quotas
- Taxes & Surcharges
- Role of Noise Metrics:
  - Overall: OASPL (dB or dBA)
  - Integral: EPNL, SEL, LAeqT, ....

# Airports with Restrictions



# Aircraft Noise Reduction

- Needs
  - Land Planning & Environmental Health
  - Aircraft Design, including sub-system
  - Optimal Flight Operations
- ICAO “Balanced Approach” to noise reduction
  - Noise reduction at source 
  - Improvements in Land Use
  - Optimal Flight Procedures 
  - Restriction of Operation (*quotas*)

# Aircraft Noise Models

**Data-Bases**

Good Accuracy

**Semi-  
Empirical**

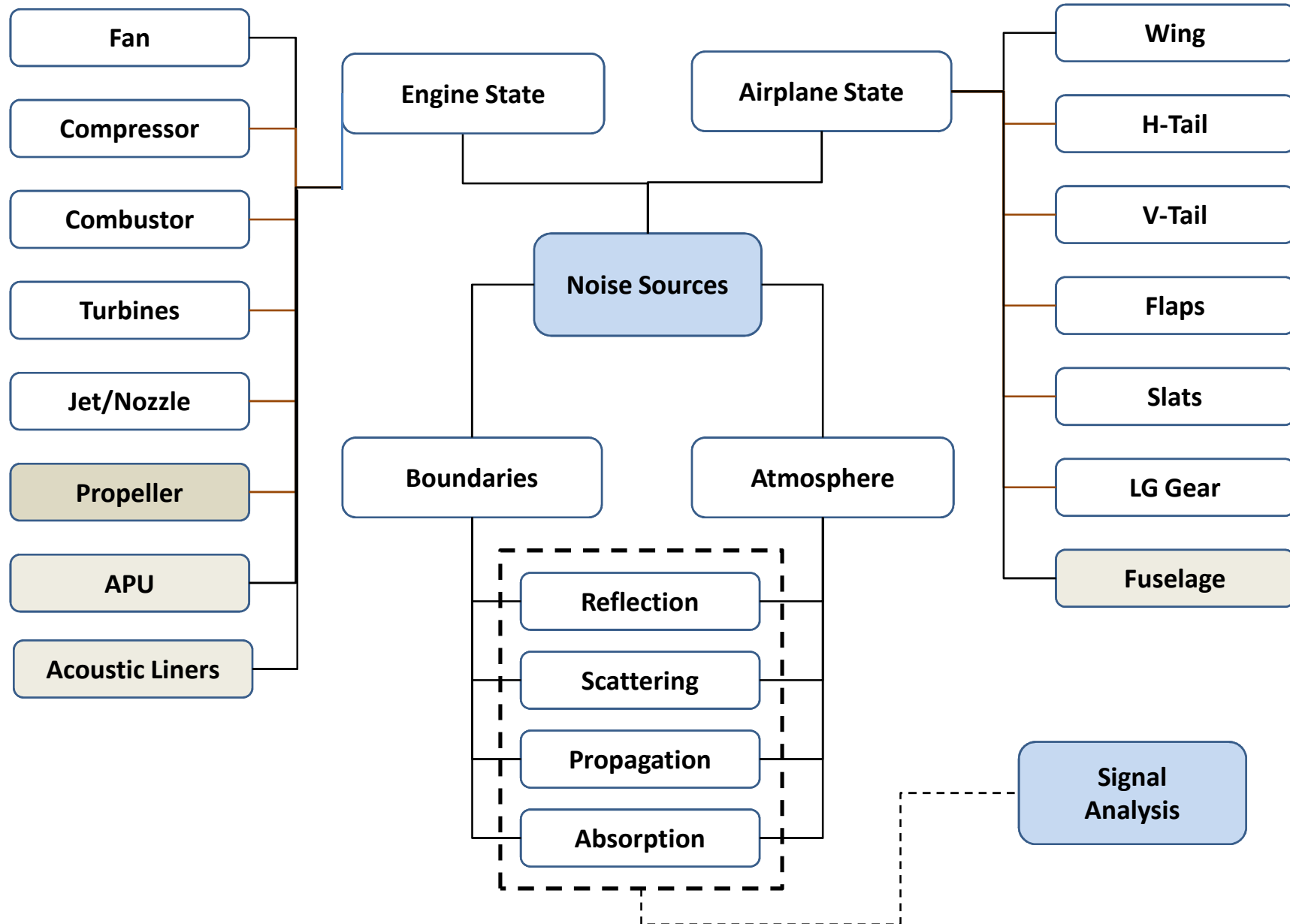
Dubious

**Physics-  
Based**

Unproven

- Empirical & Databases
  - Use in land planning, “best practice”
  - Fairly accurate on existing databases
- Physics-based
  - Modelling of emissions & propagation
  - Use in design and optimisation

# FLIGHT Noise Simulation



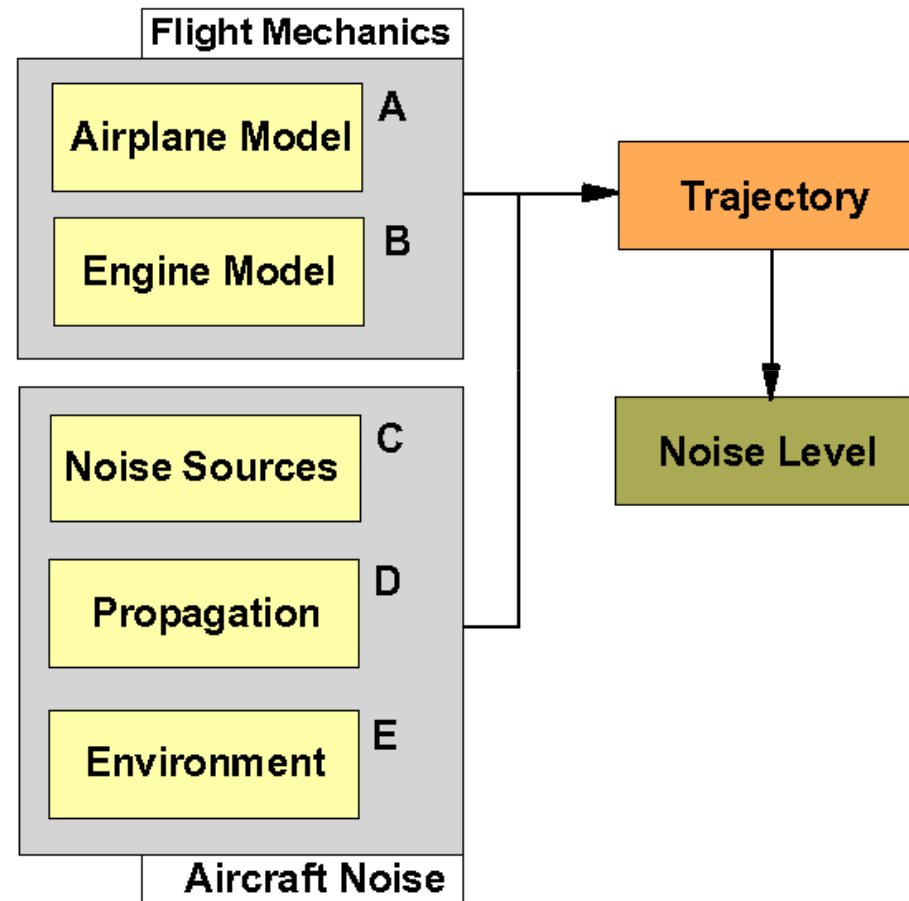
# Flight Mechanics Integration

$L \equiv \text{noisemetric} =$

$$f(t, \text{GPS}, \underline{\theta, \phi, \psi}, \text{CAS}, V, V_g, N_1, \dot{m}_f, \underline{\text{LG, SF, W}}, \underline{\underline{T, H, V_w, \Psi_w}})$$

- GPS coordinates (WGS84)
- Flight angles
- Flight speeds
- Aircraft State
- Engine State
- Atmospheric Conditions

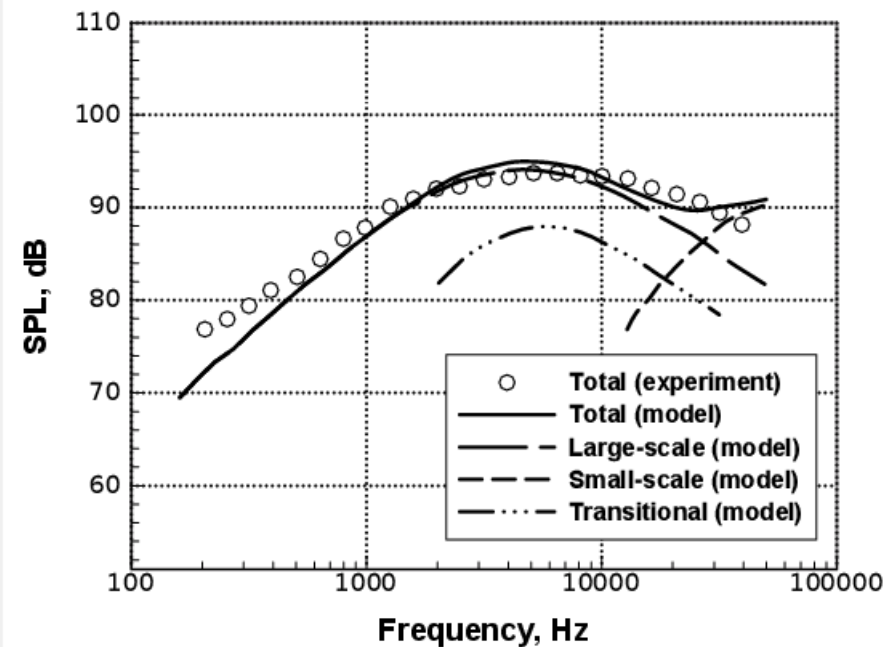
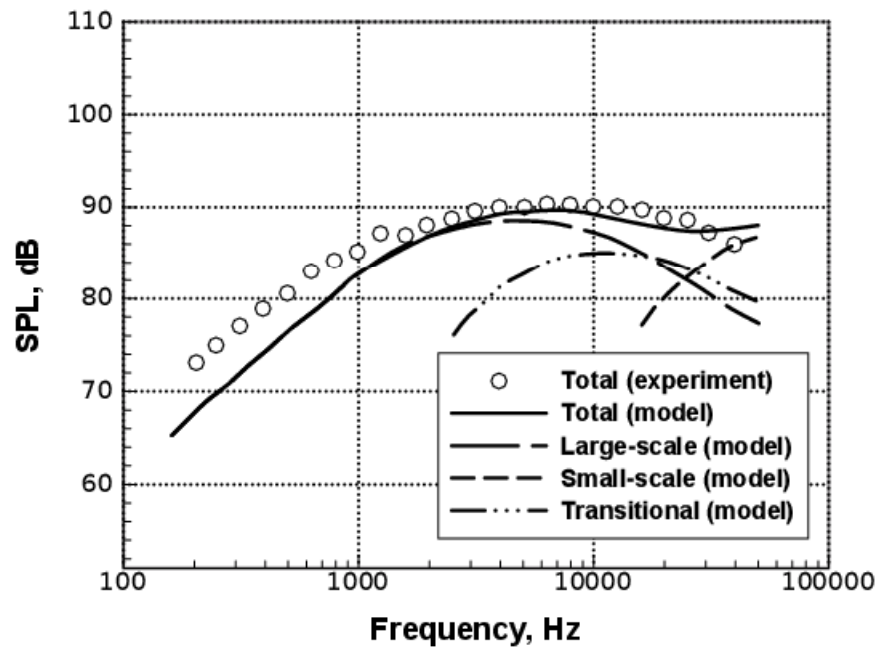
# Validation & Verification





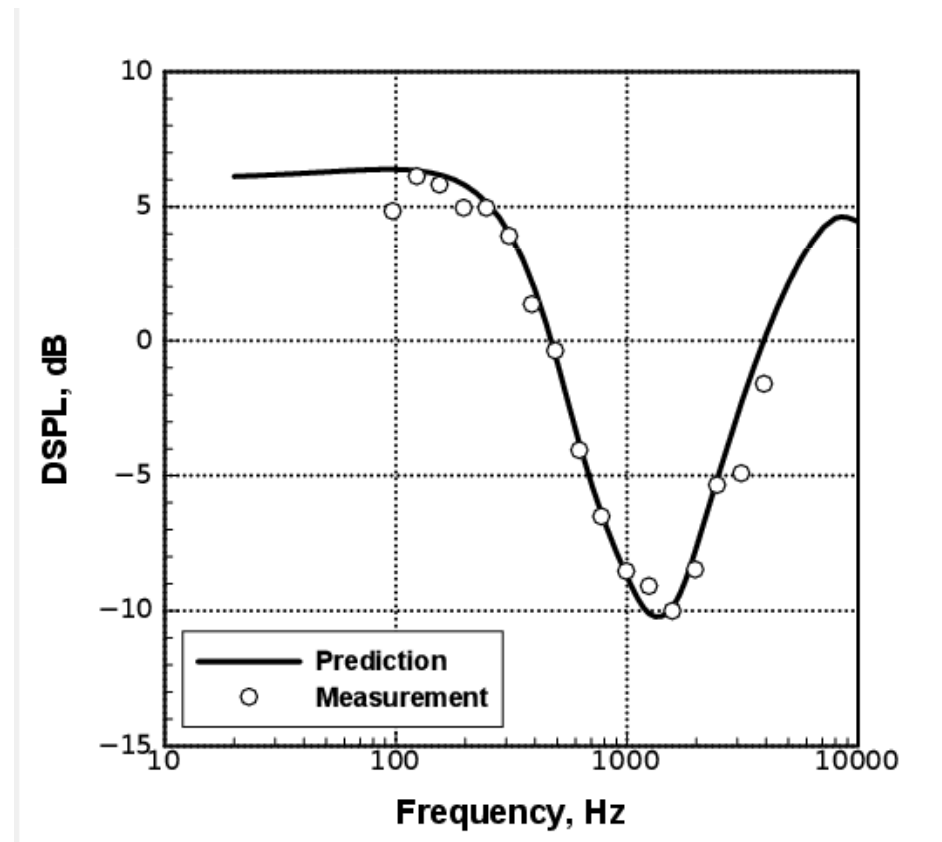
# Example: Co-axial Jet Noise

- Data from NASA (2009); Stone model (1996)



# Example: Ground Effect

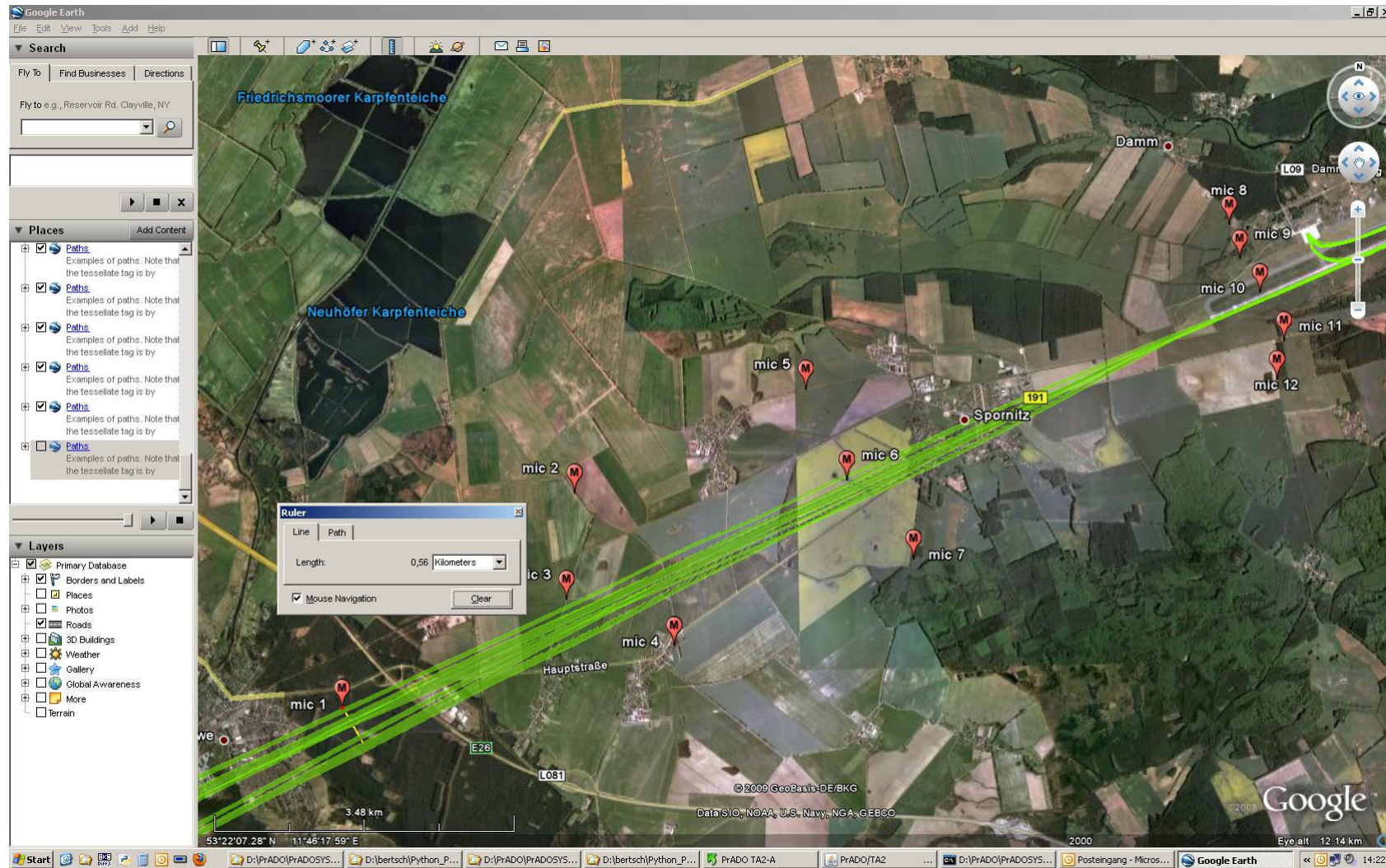
- Full spectra in 1/3 octave band,  $x = 120$  m [...]
- Ground microphones



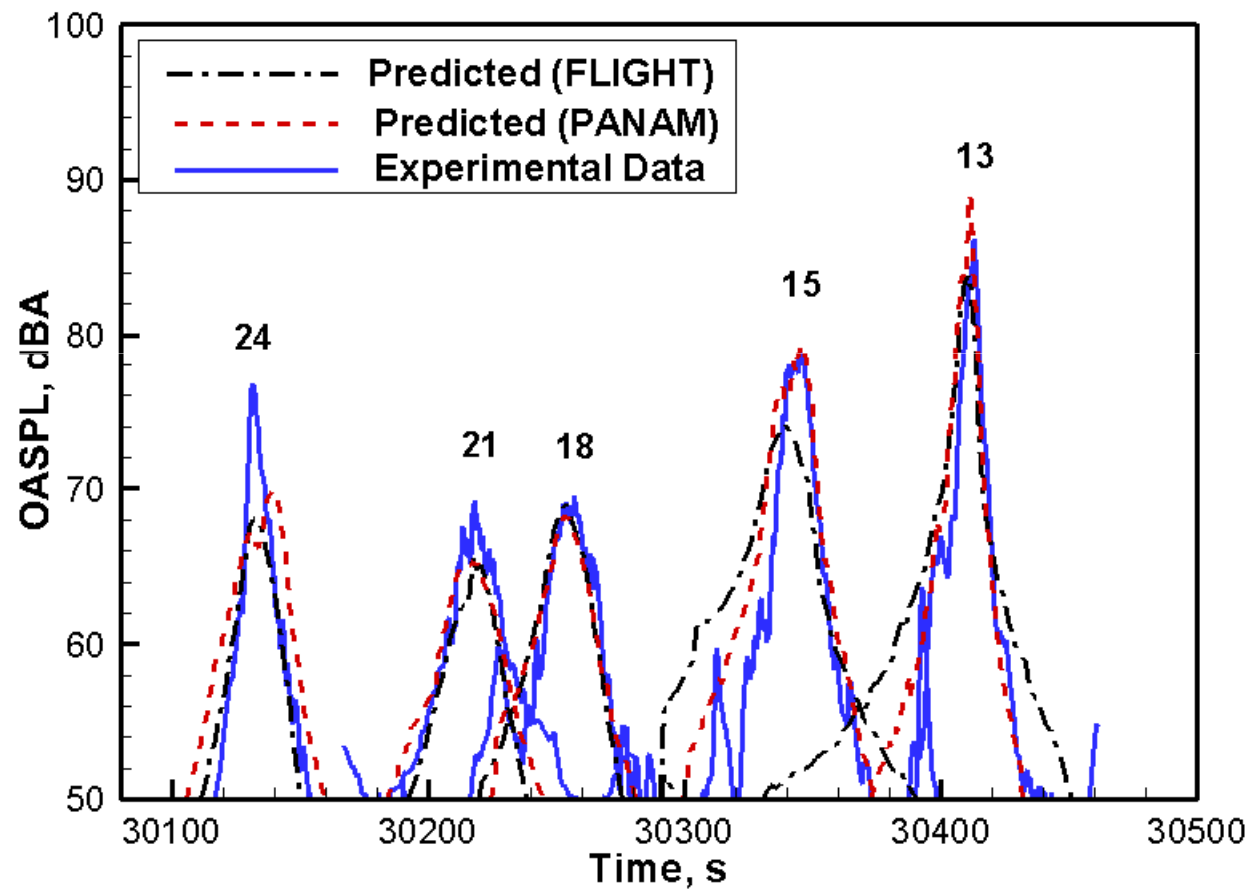
# Noise & Flight Trajectories

- Airbus A319-100-CFM56:
  - Flights: Lufthansa (2006 campaign)
  - Data processing: DLR-BS & Goettingen
  - Airfield: Parchim-Schwerin, Germany

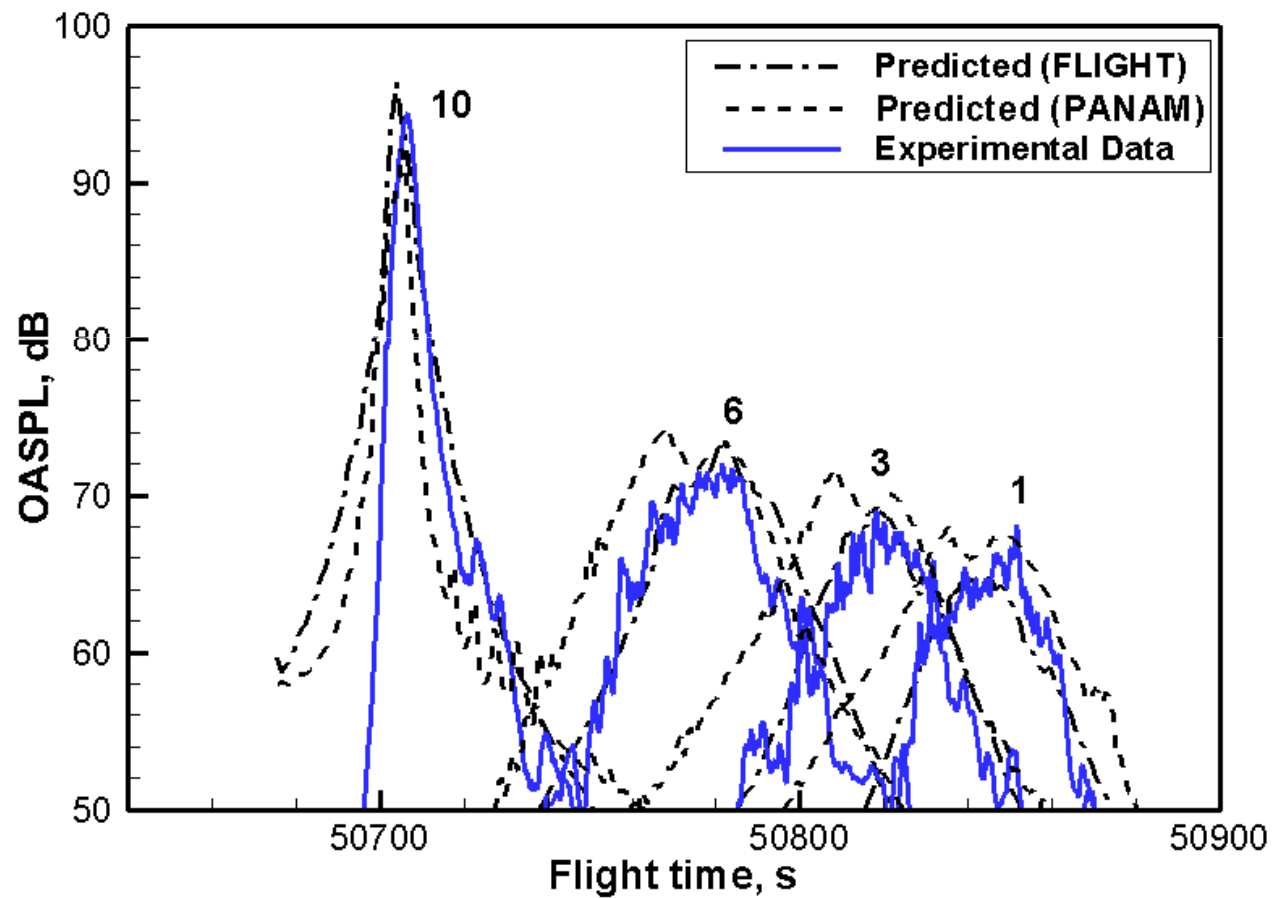
# A319- Flights: Parchim-Schwerin



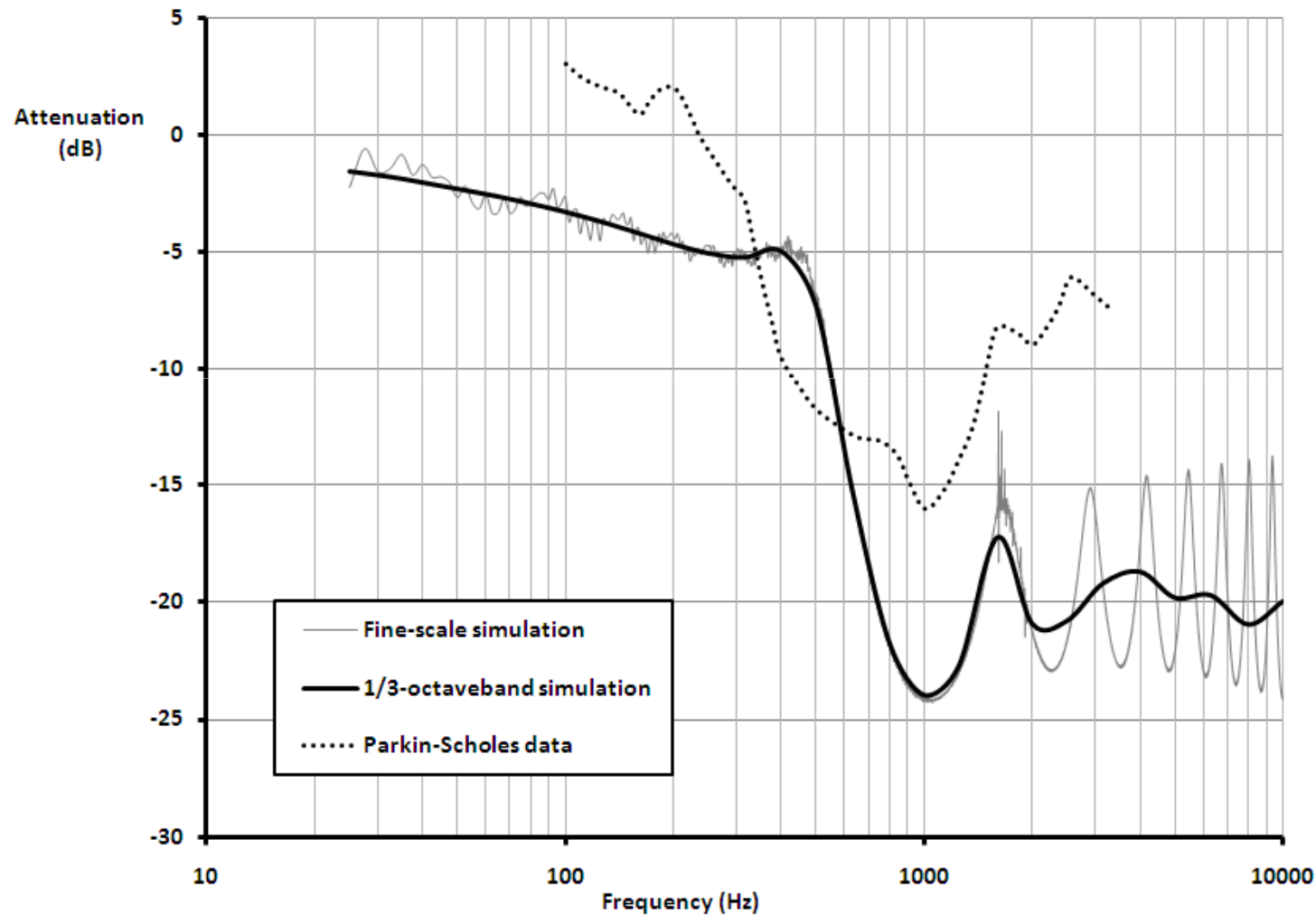
# Landing Trajectory: A319-100-CFM



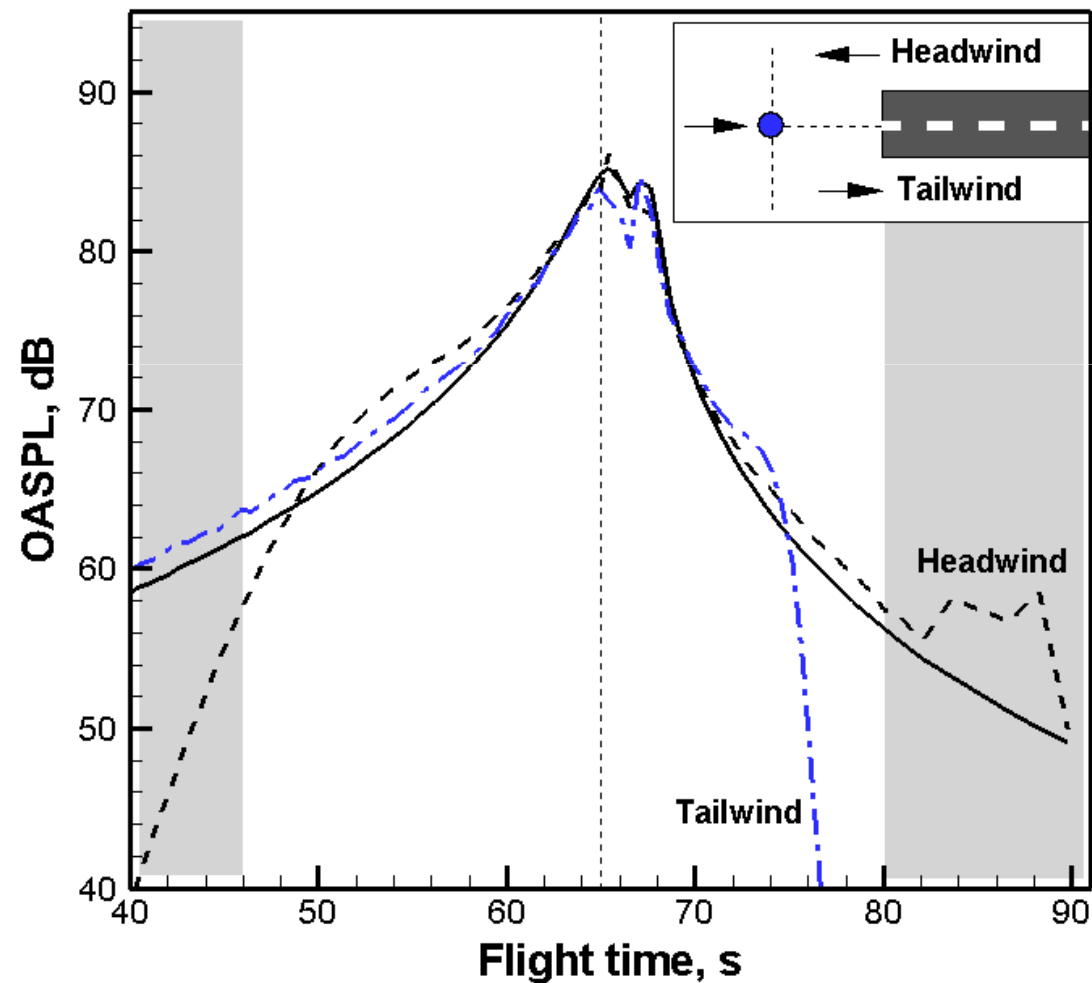
# Take-off Trajectory: A319-100-CFM



# Wind-Temperature Effects



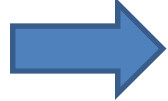
# Wind Effects: A320-211 landing





# Noise Sensitivity: Take-off

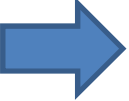
- Noise Sensitivity Matrix for +/- 2 EPNL (dB)



| Item                | EPNLt | +2dB   | -2dB   |
|---------------------|-------|--------|--------|
| <b>JET</b>          | 90.10 | 1.543  | -1.339 |
| <b>FAN</b>          | 83.73 | 0.583  | -0.471 |
| <b>Combustor</b>    | 66.88 | -0.135 | -0.010 |
| <b>LPT</b>          | 66.00 | -0.142 | -0.009 |
| <b>Wing</b>         | 57.49 | -0.148 | -0.006 |
| <b>H-Stabiliser</b> | 49.08 | -0.151 | 0.000  |

# Noise Sensitivity: Landing

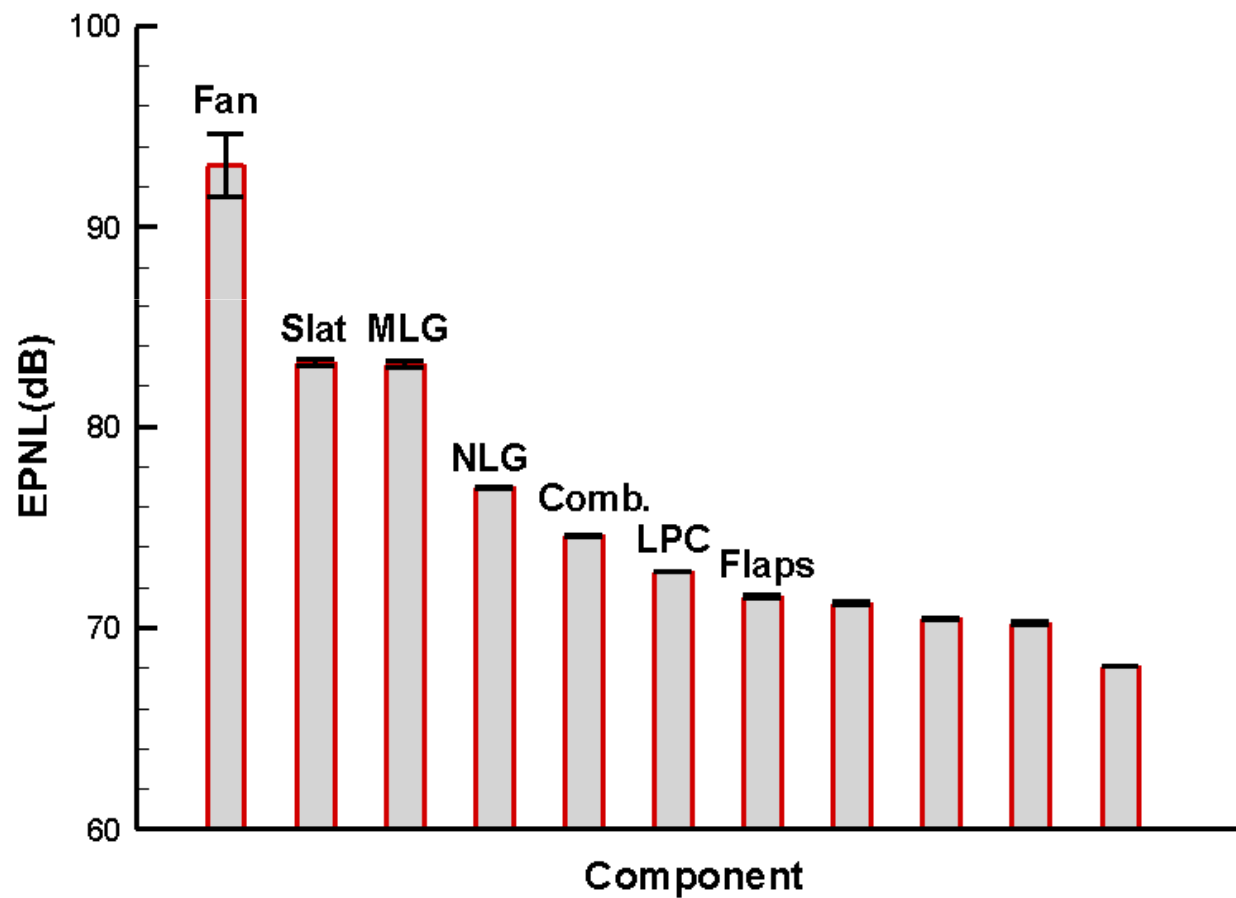
- Noise Sensitivity Matrix for +/- 2 EPNL (dB)



| Item               | EPNLt | +2dB  | -2dB   |
|--------------------|-------|-------|--------|
| <b>FAN</b>         | 92.98 | 1.685 | 0.093  |
| <b>Slats</b>       | 83.11 | 0.187 | -0.118 |
| <b>Main L-Gear</b> | 82.94 | 0.453 | -0.027 |
| <b>Nose L-Gear</b> | 76.86 | 0.255 | -0.164 |
| <b>Combustor</b>   | 74.27 | 0.070 | -0.011 |
| <b>LPC</b>         | 74.00 | 0.017 | 0.120  |

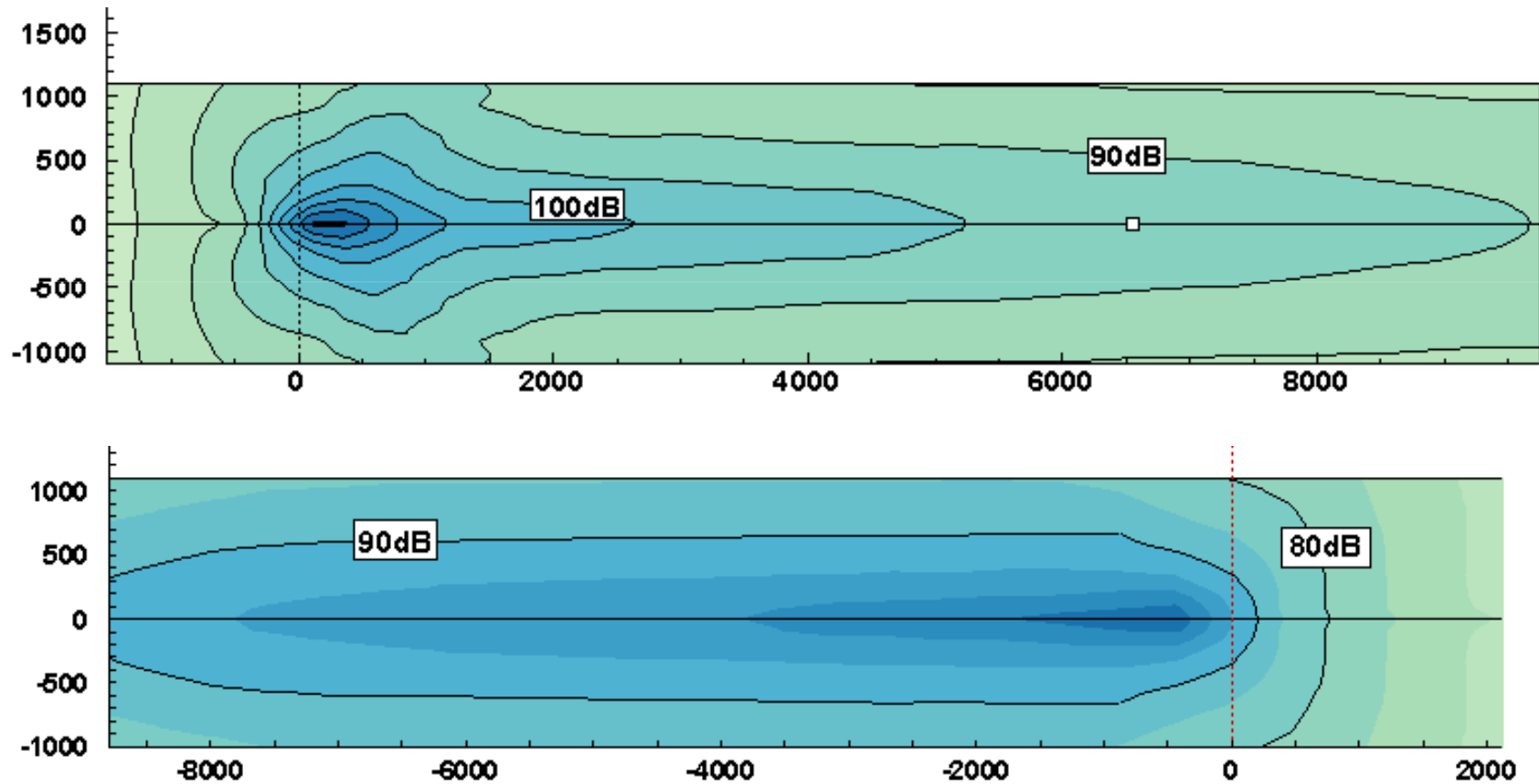
# Noise Bar-Chart A320-211-CFM

- Landing



# Case Study: Noise Footprints

- Boeing B777-300-GE, takeoff and landing



# Conclusions

- There is a need to predict aircraft noise at several levels.
- System validation is a driver
- Present results offer engineering insight
- Lack of recognised standards in noise validation
- All sub-models rationally to be validated with experimental data or FDR data
- *Airplane model is the most accurate & comprehensive outside manufacturers.*

# Some Research Needs

- Noise Propagation over Long Distances
- Effects of topography on propagation
- Noise of rotating components
- Noise of less conventional systems
- APU Noise
- Noise shielding and interference
- Trajectory Optimisation Models
- Validation Standards