Noise Reduction Potential of Large, Over-the-Wing Mounted, Advanced Turbofan Engines

XIV ISABE

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Introduction

Two Future Aircraft Design Issues:

♦ Increasingly stringent civilian aviation noise regulations will require the design of extremely quiet commercial aircraft.

♦ The large fan diameters of modern, increasingly higher bypass ratio engines pose a significant packaging and aircraft installation challenge.

One design approach that addresses both of these challenges is to mount the engines above the wing.

Advantages:

- ♦ Noise insertion loss
- ♦ Fan diameter
- ♦ Landing Gear
- ♦ Coanda effect

Disadvantages:

- ♦ Maintenance
- ♦ Cabin noise
- ♦ Stability & Control
- ♦ Unconventional

NASA Aeronautics Noise Goal: Reduce the perceived noise levels of future aircraft by a factor of two (10 EPNdB) from today's subsonic aircraft within 10 years, and by a factor of 4 (20 EPNdB) within 25 years.

Introduction (2)

Over-the-Wing Engine Mounting: Why Now?

Then:

♦ Earlier efforts were applied to older, lower bypass engines, and limited benefits were shown.

⇒ High jet noise (distributed source)
⇒ High fan inlet radiated noise

♦ Wing chord insufficiently large to effectively shield both ends of the engine.

Now:

♦ Modern high overall pressure and bypass ratios result in much lower jet noise.

♦ Noise of modern, highly loaded, wide chord fan blades dominated by discharge noise.

Expectation is that wing barrier noise shielding will be much more effective for ultra high bypass engines.

Method of Analysis

Source Noise Modeling:

♦ Fan: Pratt & Whitney/NASA Advanced Ducted Propulsor (Low Noise Fan #1) experimental data

⇒ 1/6 scale model tunnel data
⇒ Design tip speed: 850 ft/s
⇒ Design pressure ratio: 1.28
⇒ 2 degree of freedom acoustic liner

♦ Jet: Modified, semiempirical Stone method after P&W ultrahigh bypass data

♦ Core: Matta method

♦ Airframe: Fink method

Noise Propagation Modeling:

♦ Noise insertion loss: Classic Maekawa diffraction theory; applied to fan and core noise only

♦ Atmospheric and other effects:

⇒ Atmospheric attenuation
⇒ Ground attenuation/reflections
⇒ Convective amplification
⇒ Spherical spreading

Method of Analysis (2)

Engine Cycle Modeling:

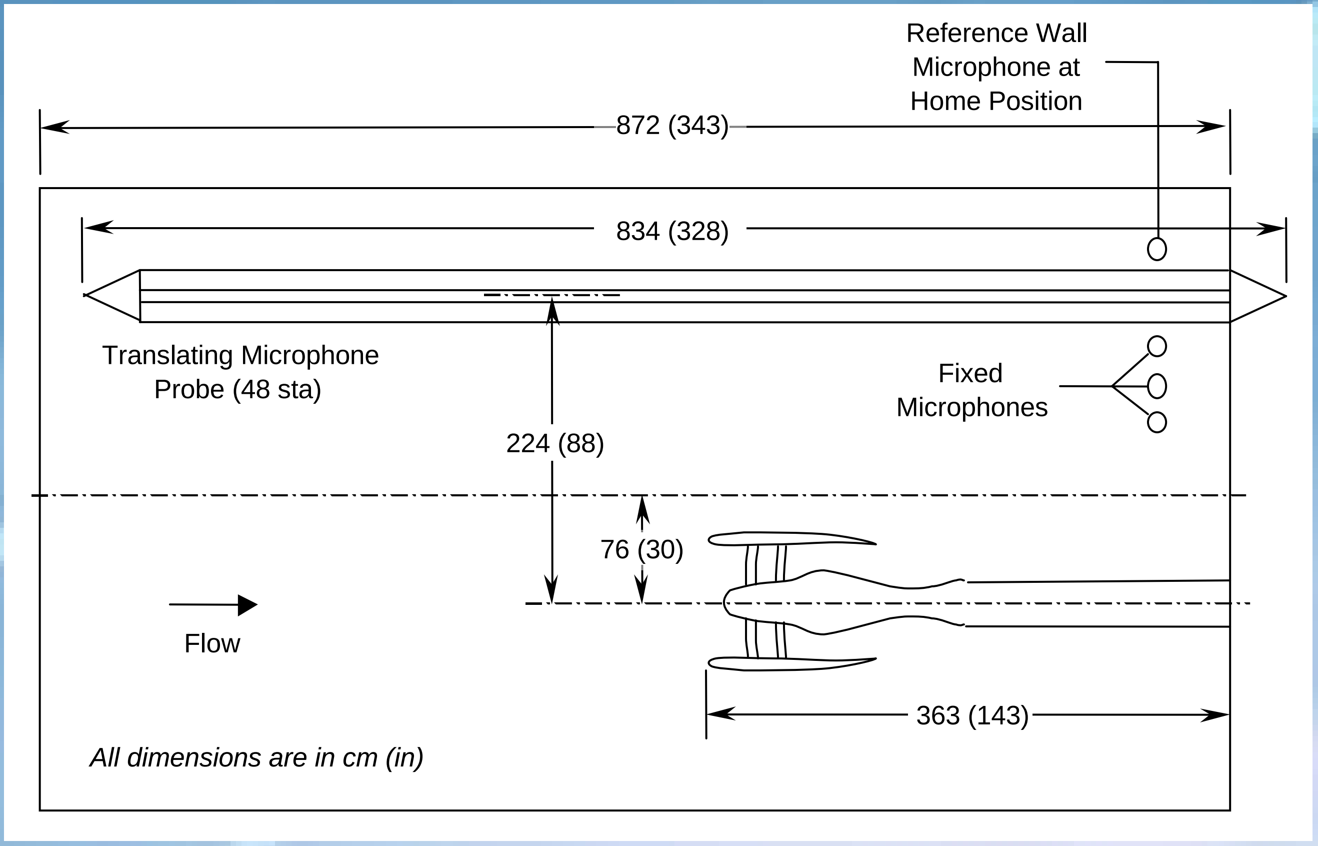
- One dimensional thermodynamic cycle analysis
- 55,000 pound thrust class
- Very high bypass ratio (13.5)
- Low speed, low noise, Advanced Ducted Propulsor geared fan

Aircraft Modeling:

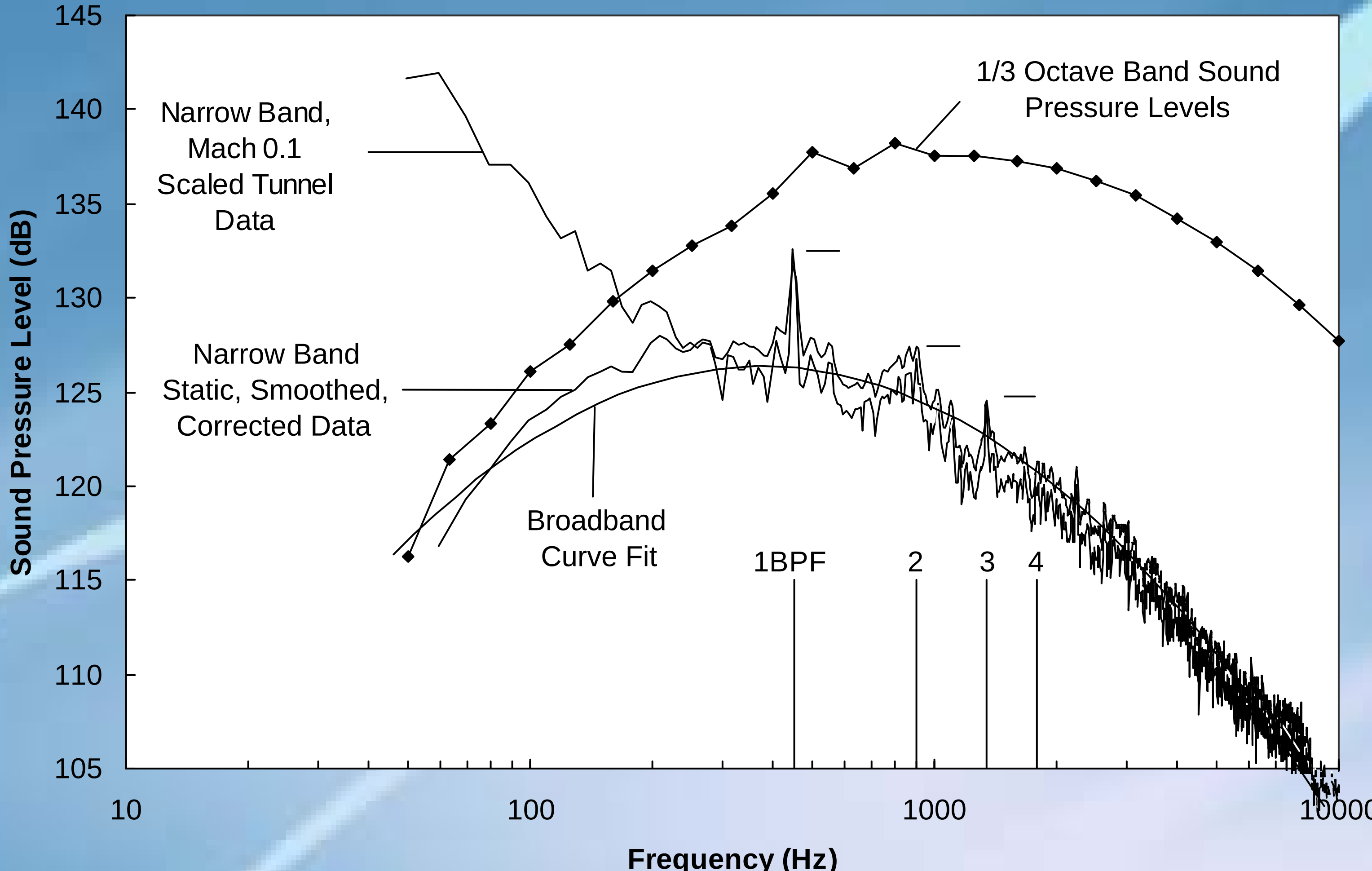
- Long haul, heavy, quad jet aircraft
  - ⇒ Long chord lengths
  - ⇒ Regulation compliance difficulty
  - ⇒ Entry into service circa 2020

P&W Low Noise Fan #1
in NASA Glenn 9x15 Low Speed Wind Tunnel

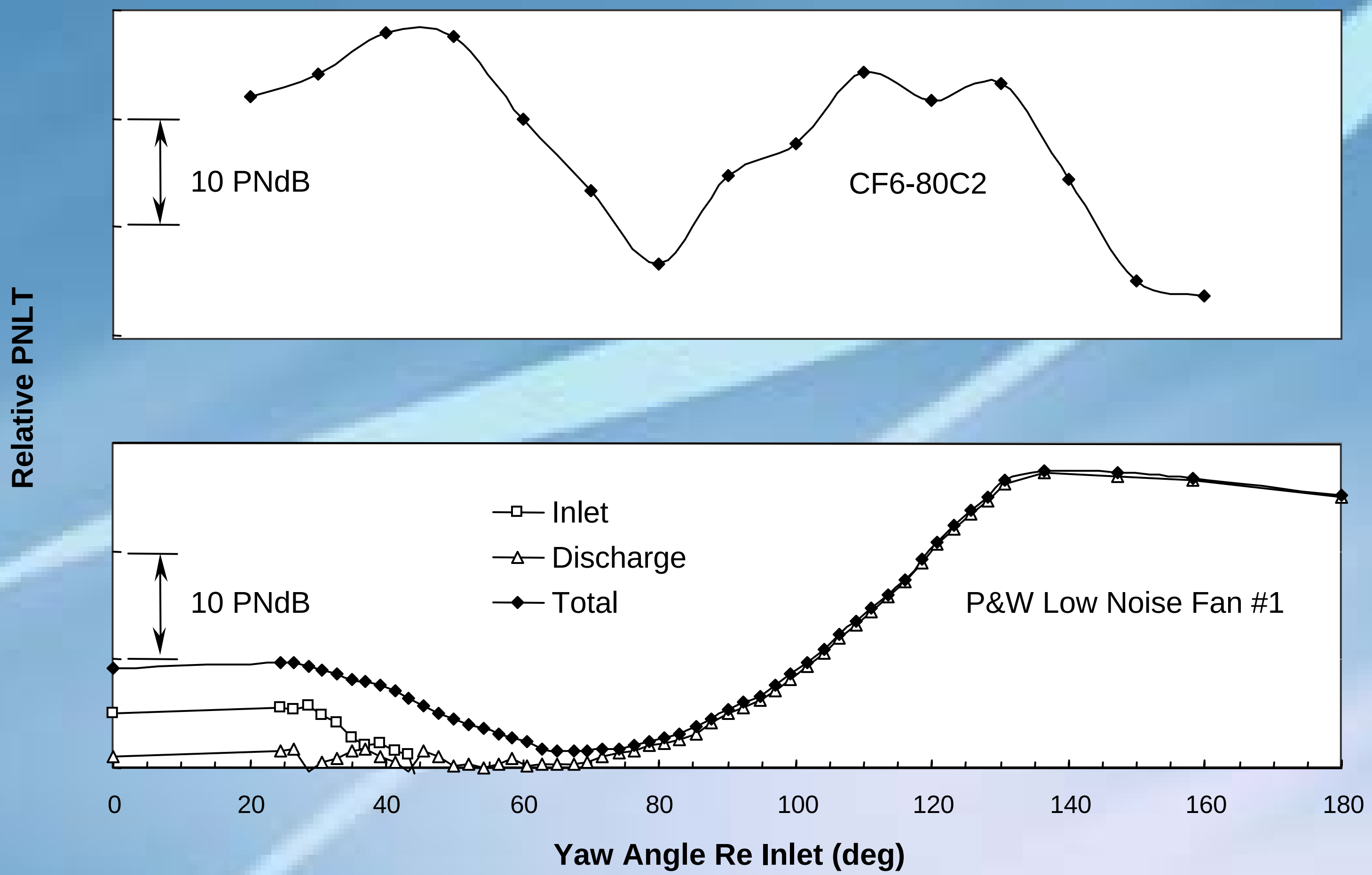
P&W Low Noise Fan #1
in NASA Glenn 9x15 Low Speed Wind Tunnel



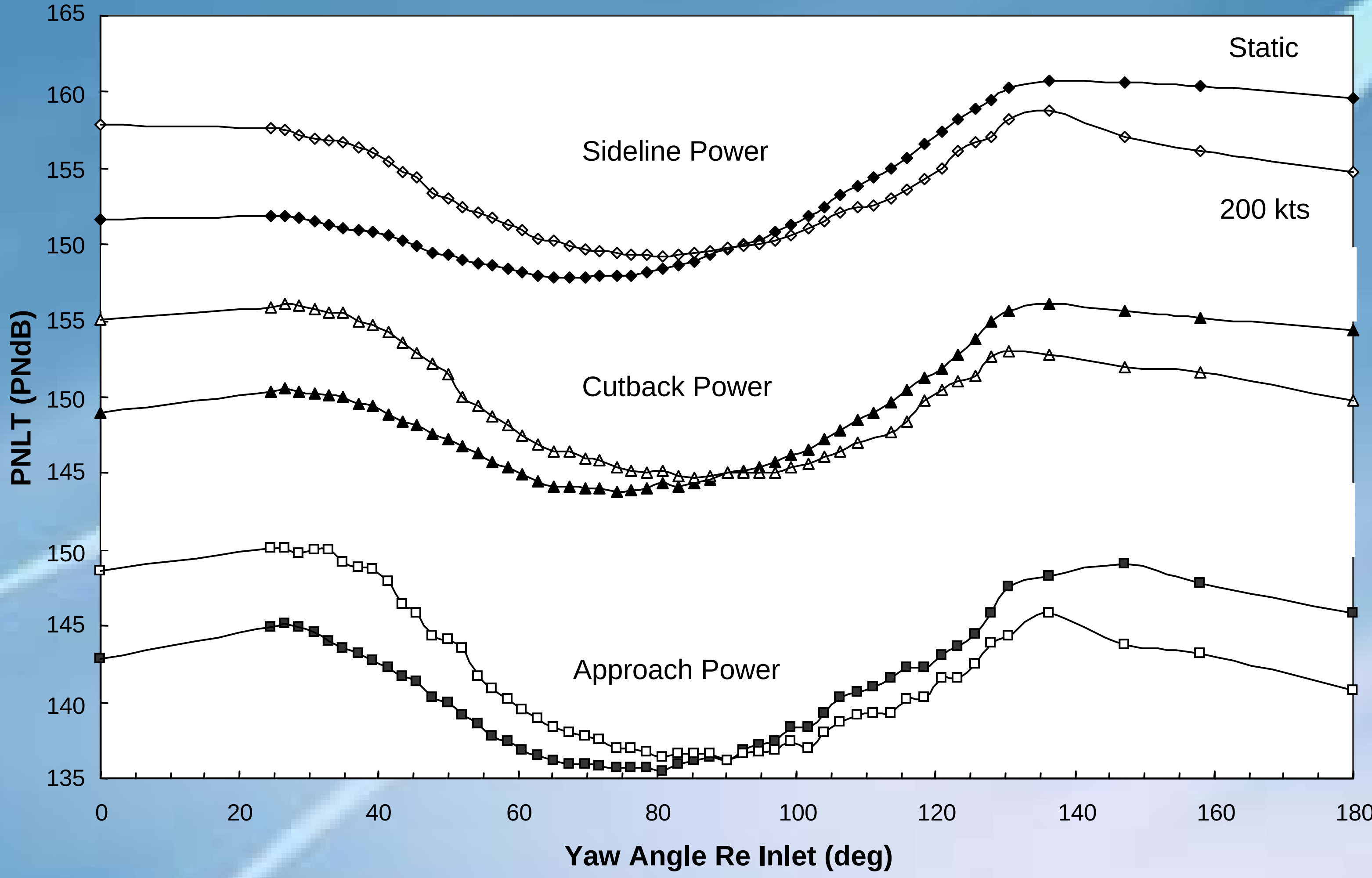
Experimental Fan Noise Data Reduction



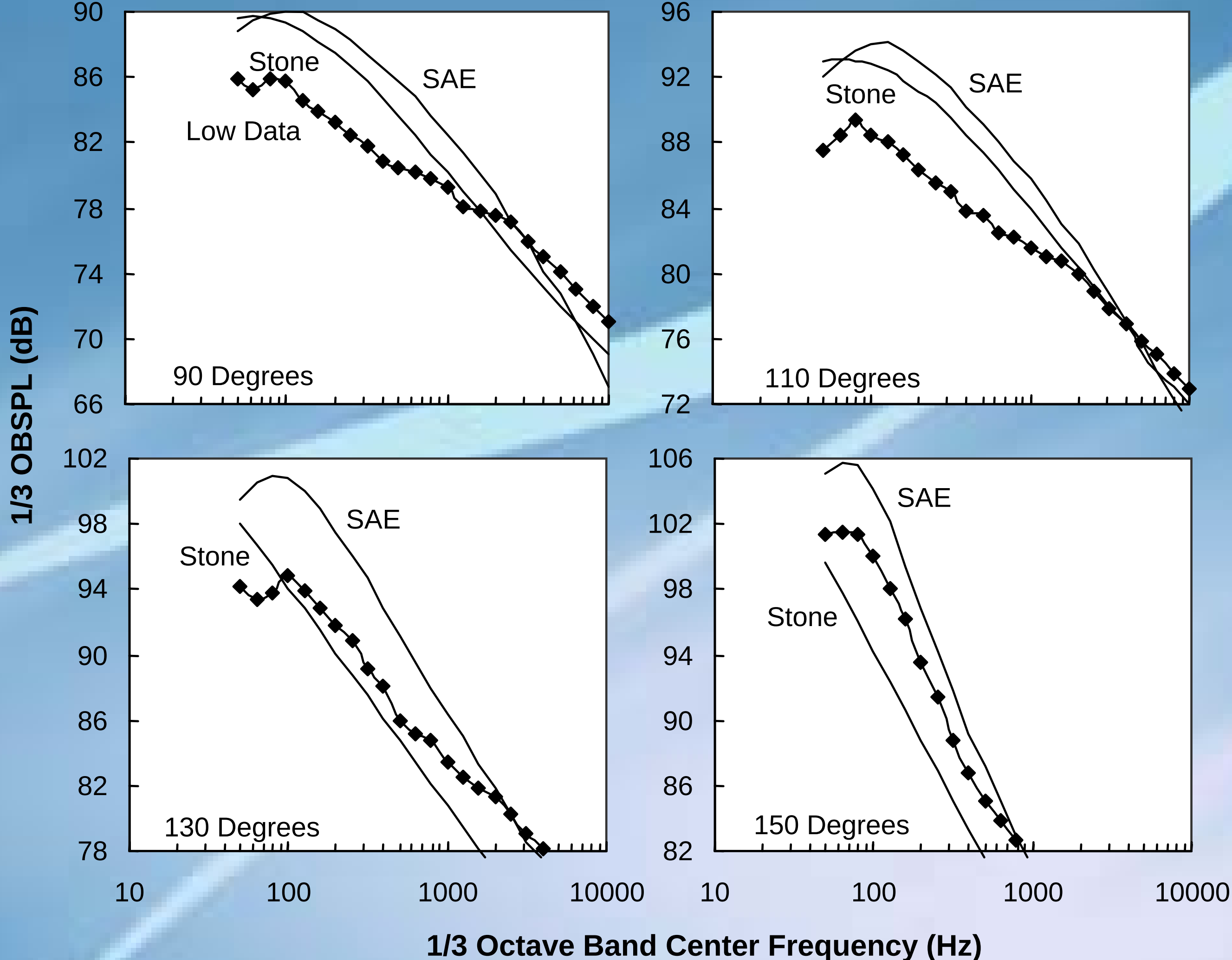
Static Fan Noise Comparison



Experimental Fan Data at Certification Power Settings



High Bypass Jet Noise Modeling



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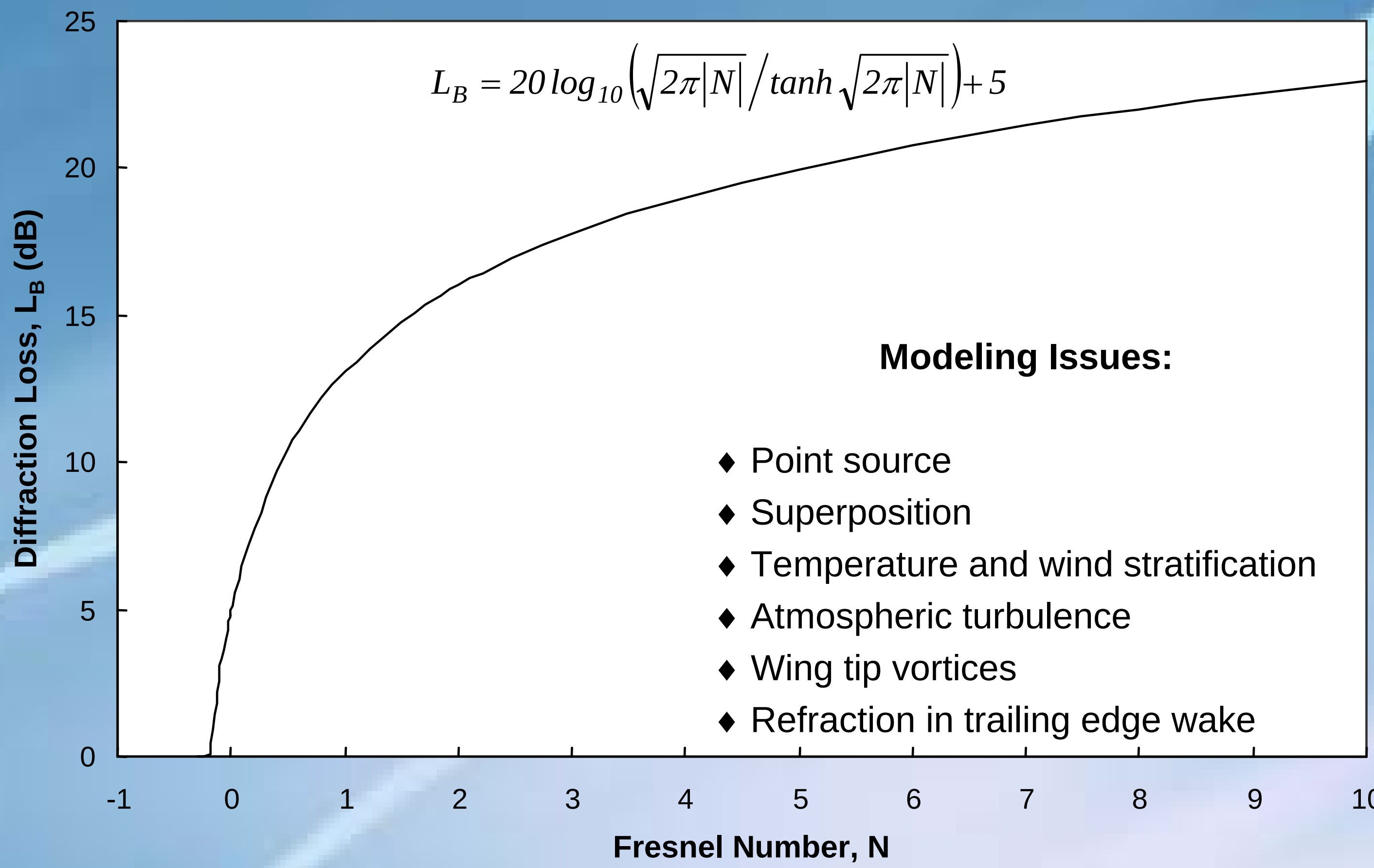
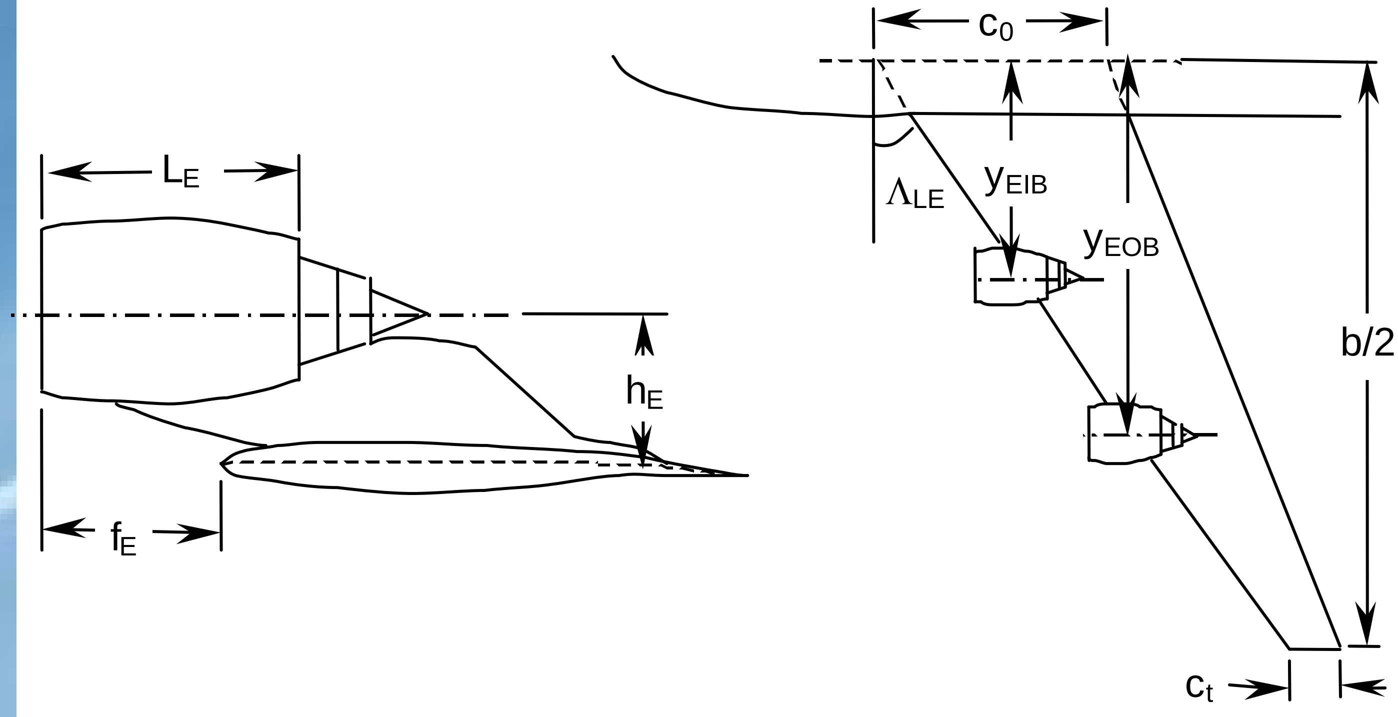
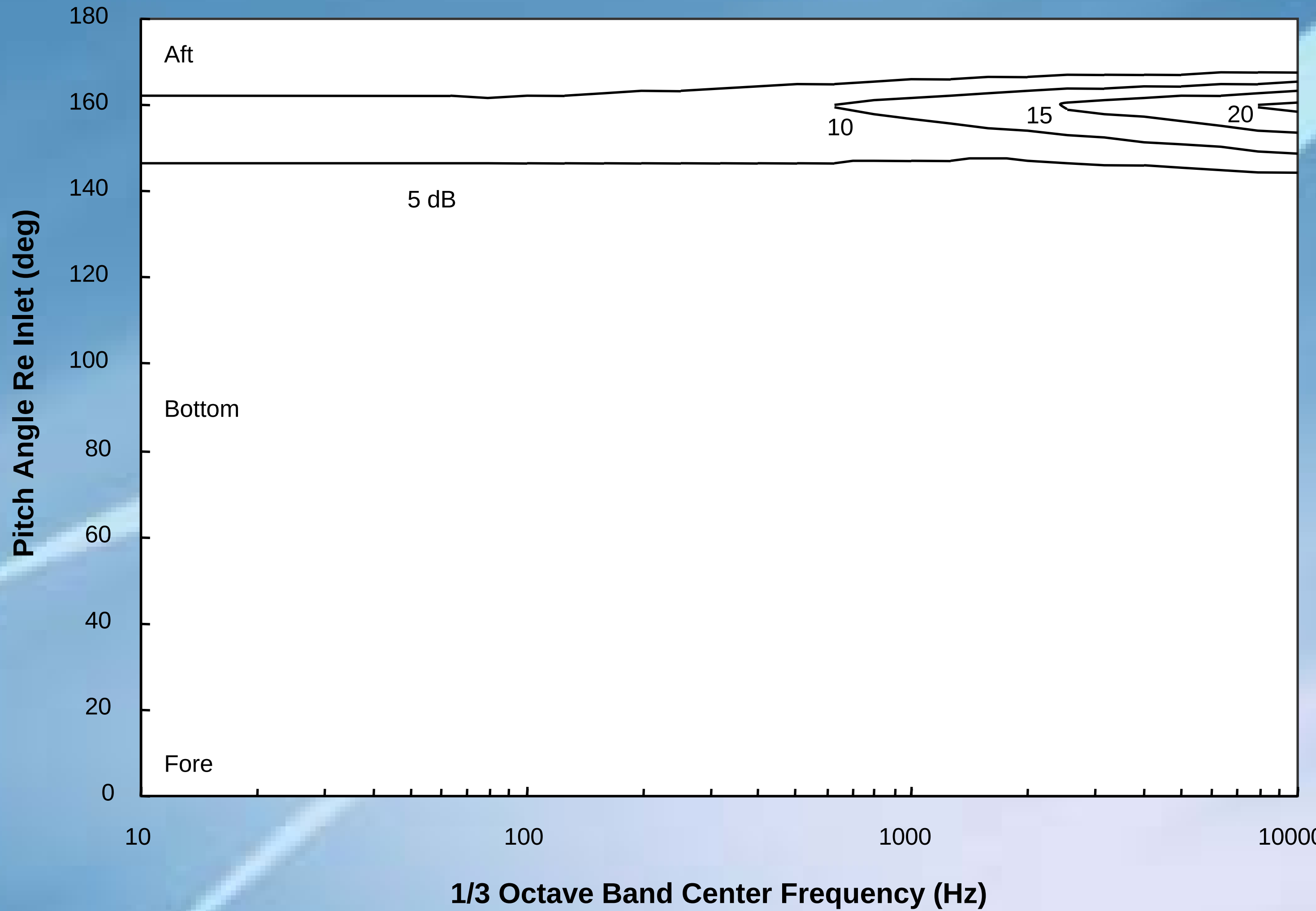
Barrier Diffraction Analysis



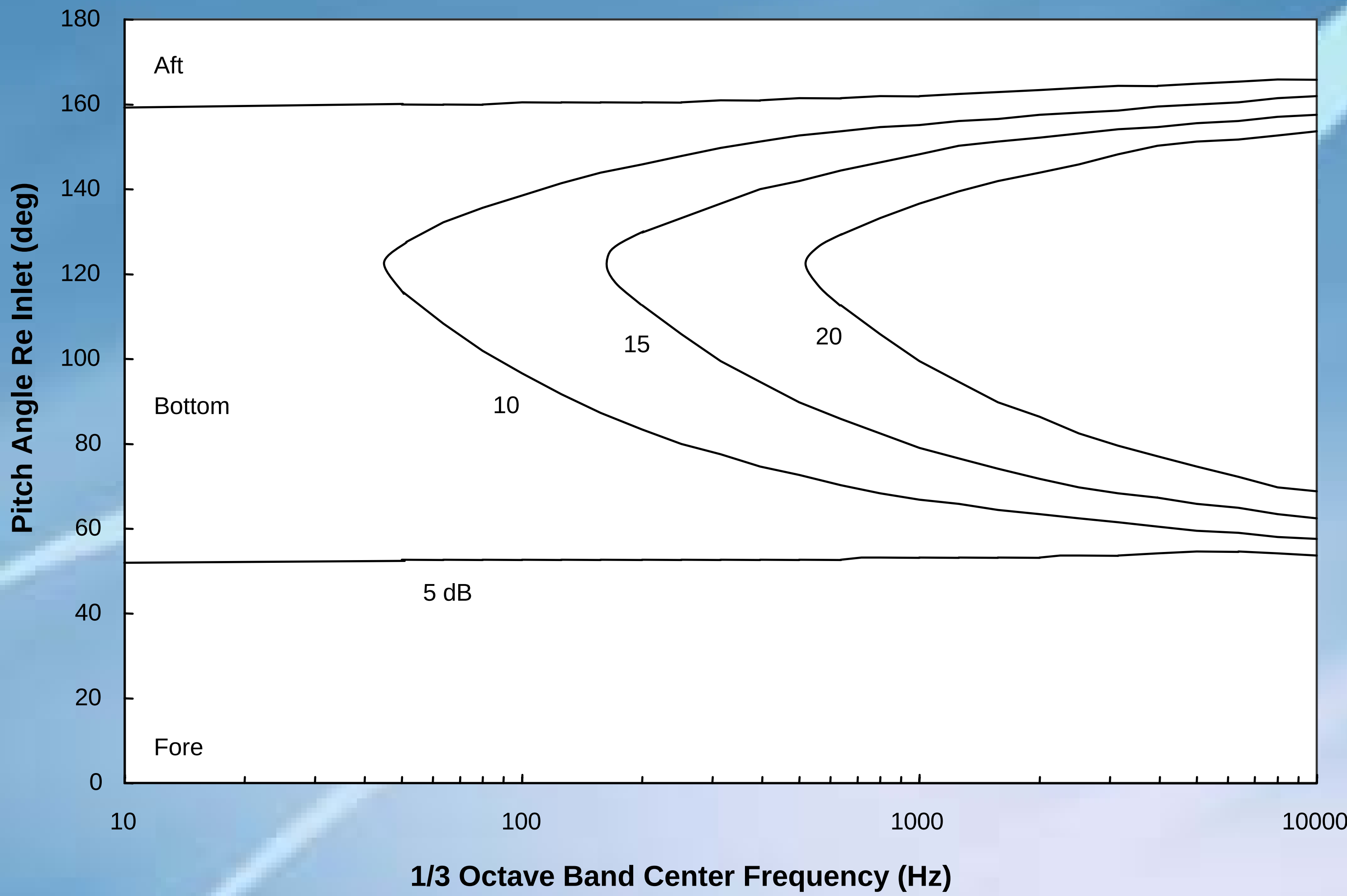
General Arrangement of circa 2020 Conceptual Quad Aircraft



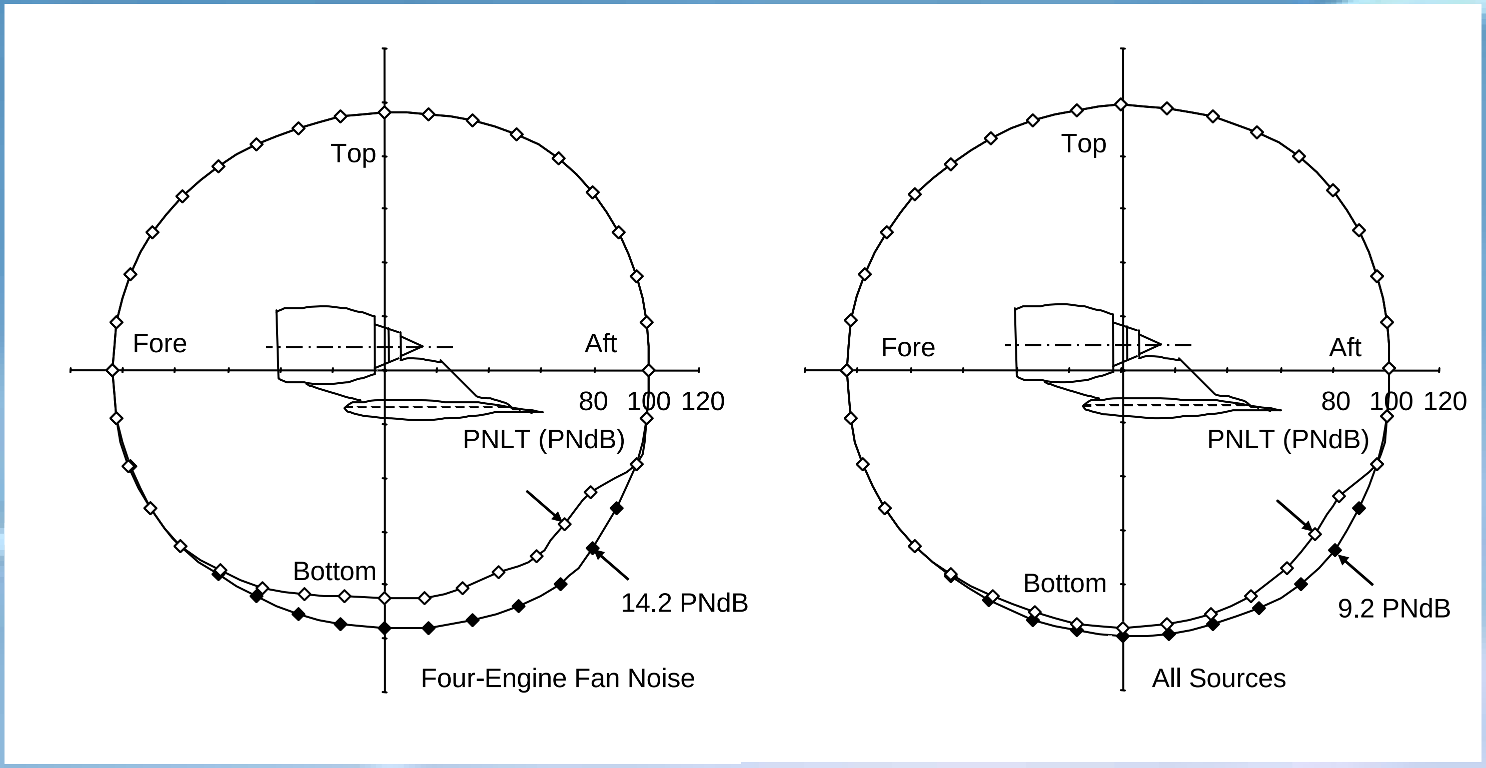
Inlet Barrier Attenuation



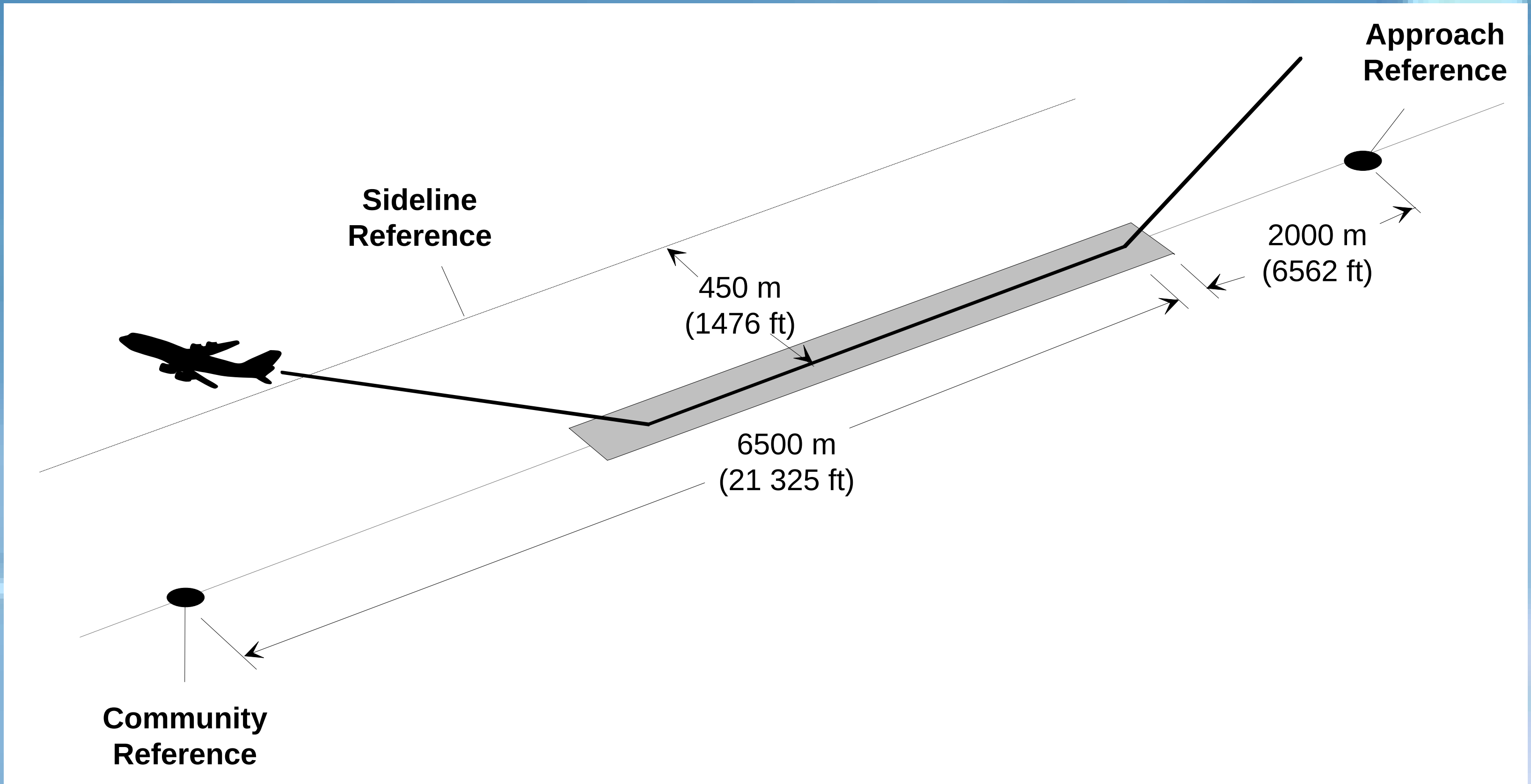
Discharge Barrier Attenuation



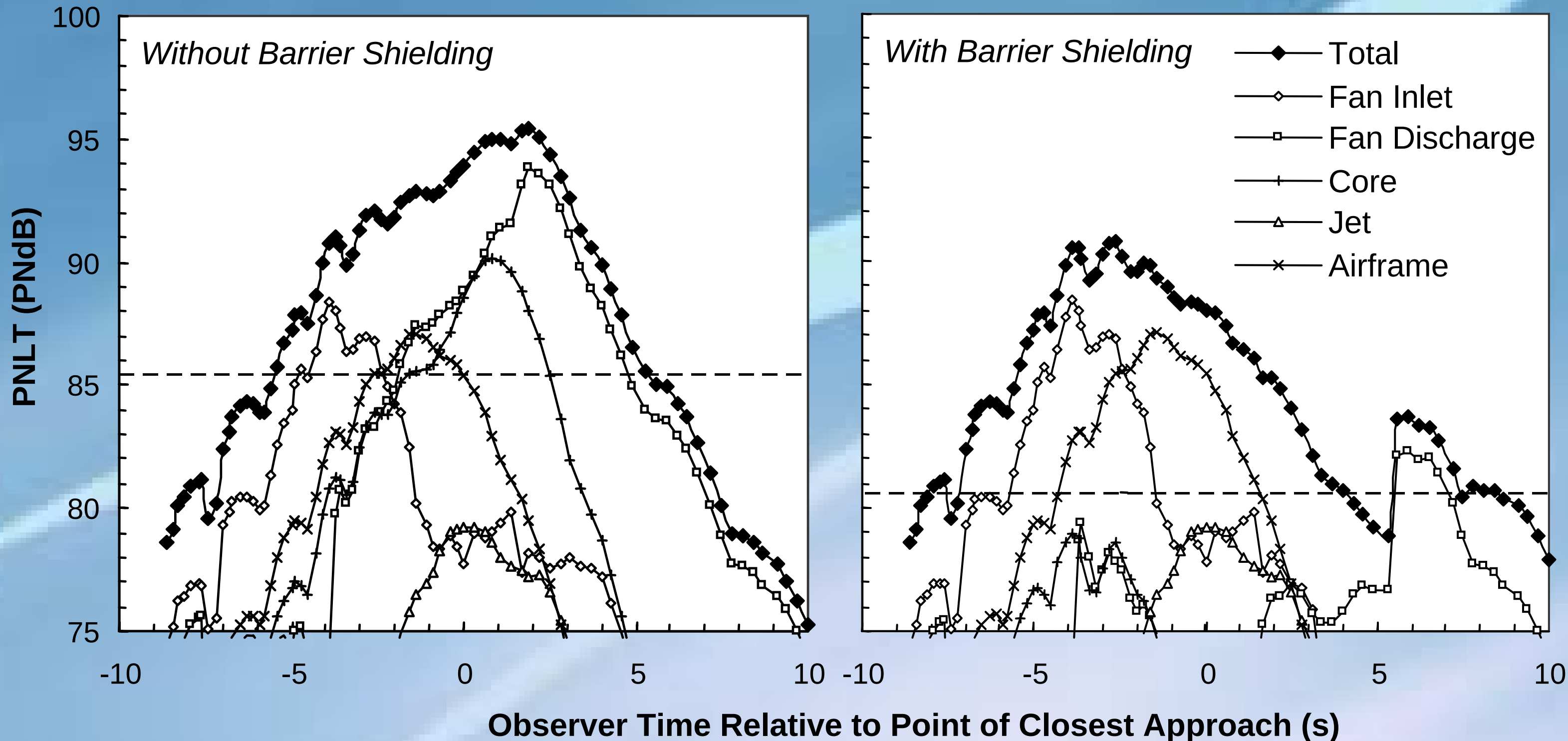
Noise Level Variation in Pitch Angle; with and without Wing Barrier Calculations



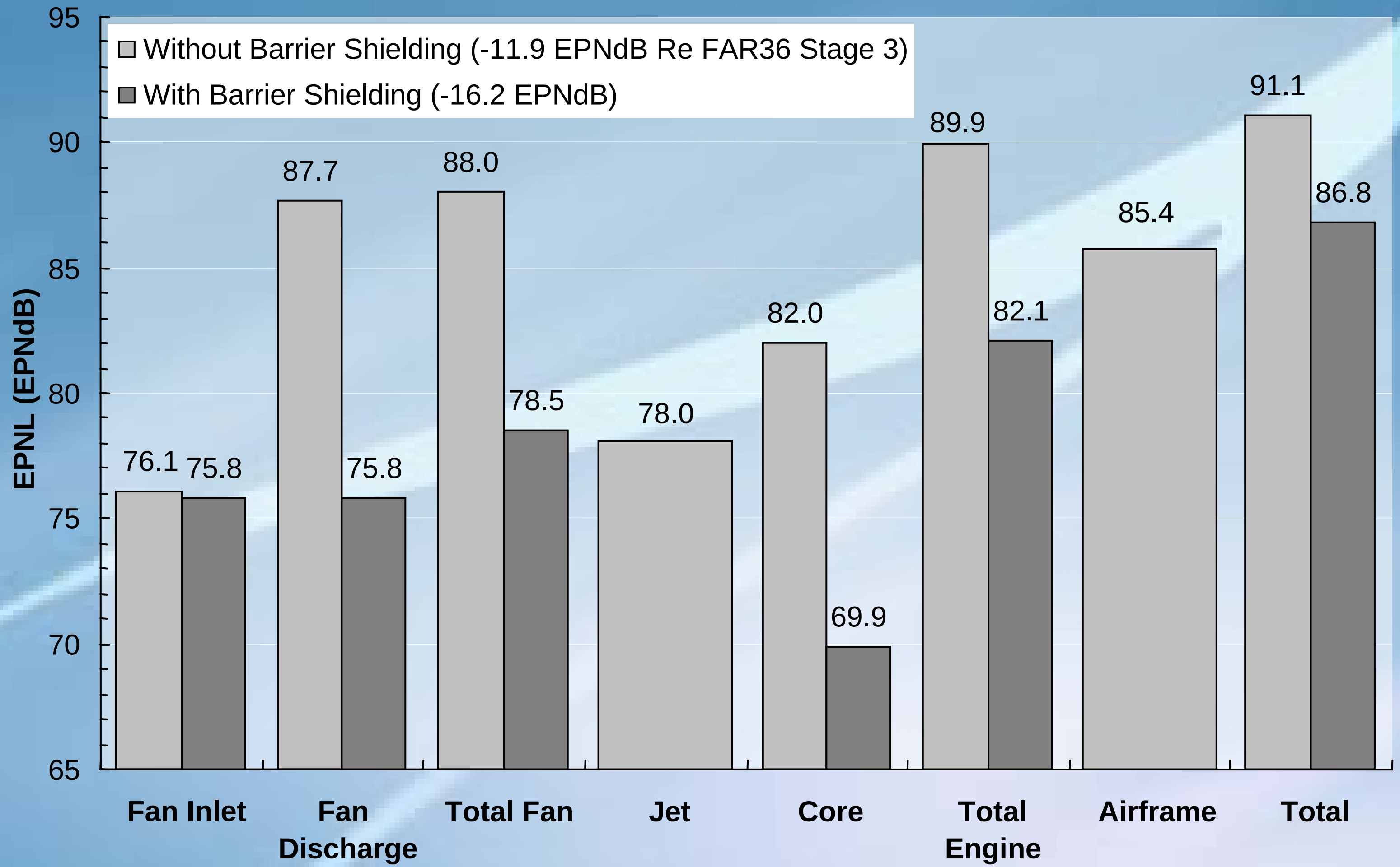
Reference Trajectory and Observer Locations



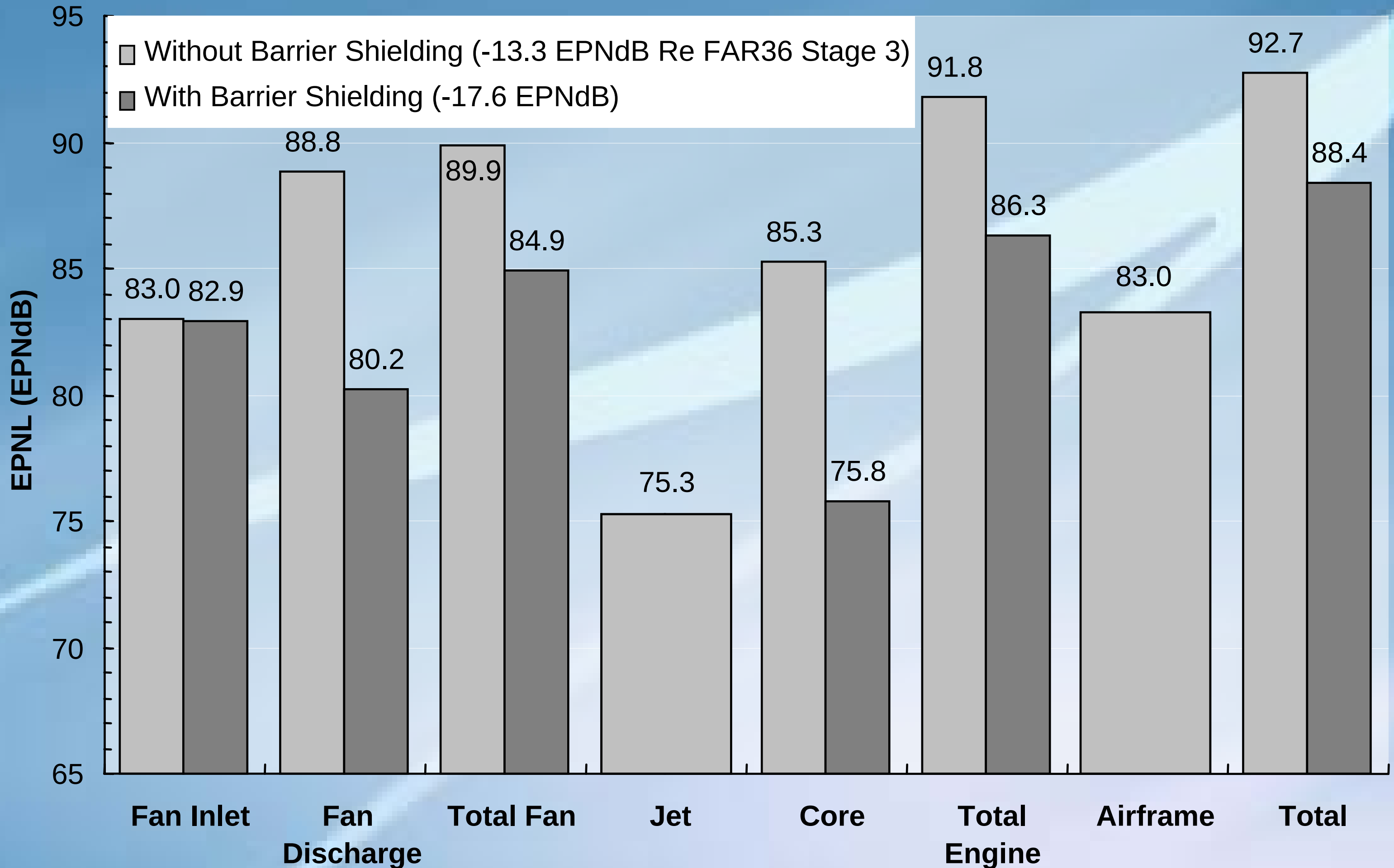
Community Observer Noise Histories; with and without Wing Barrier Calculations



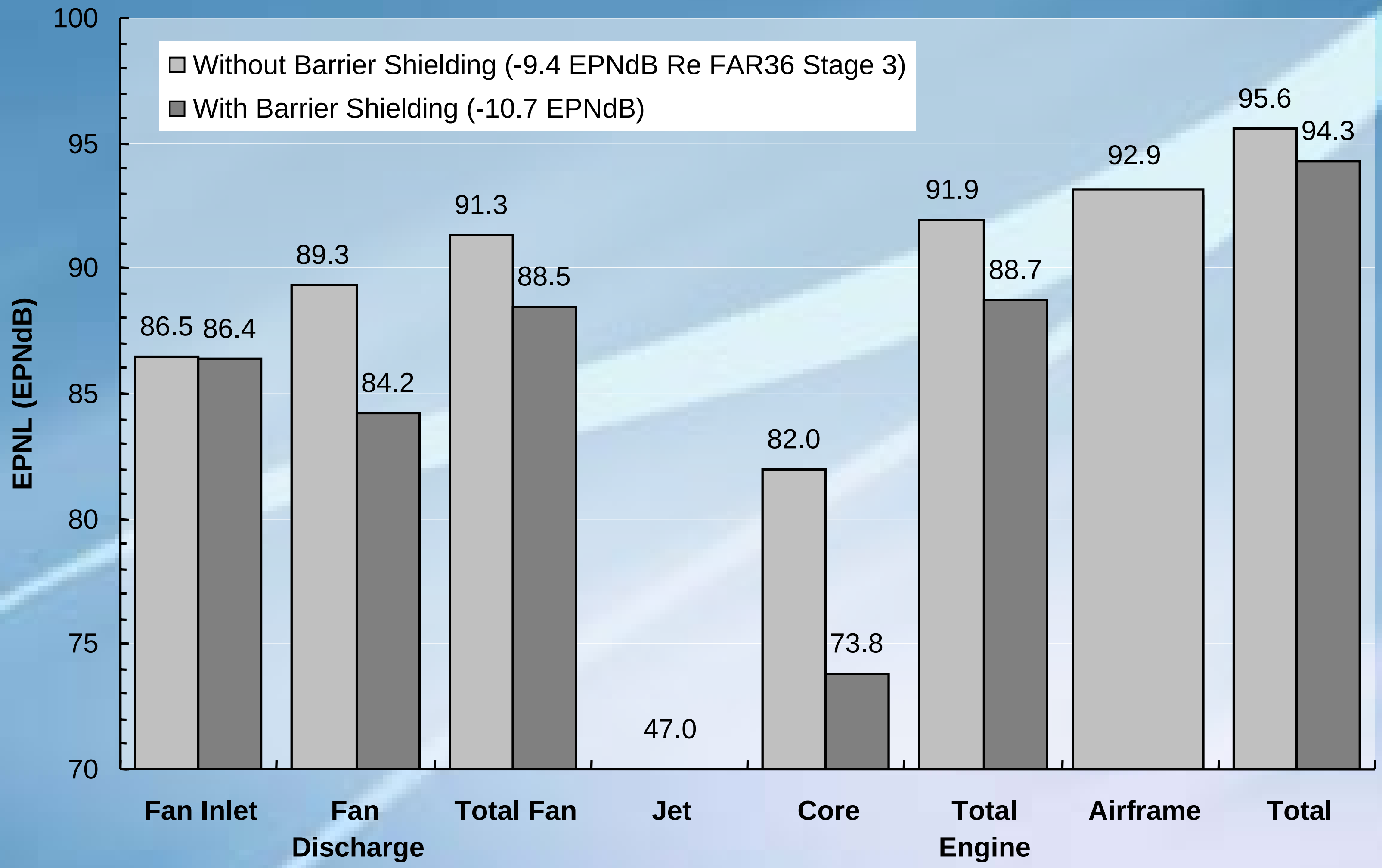
Sideline EPNLs



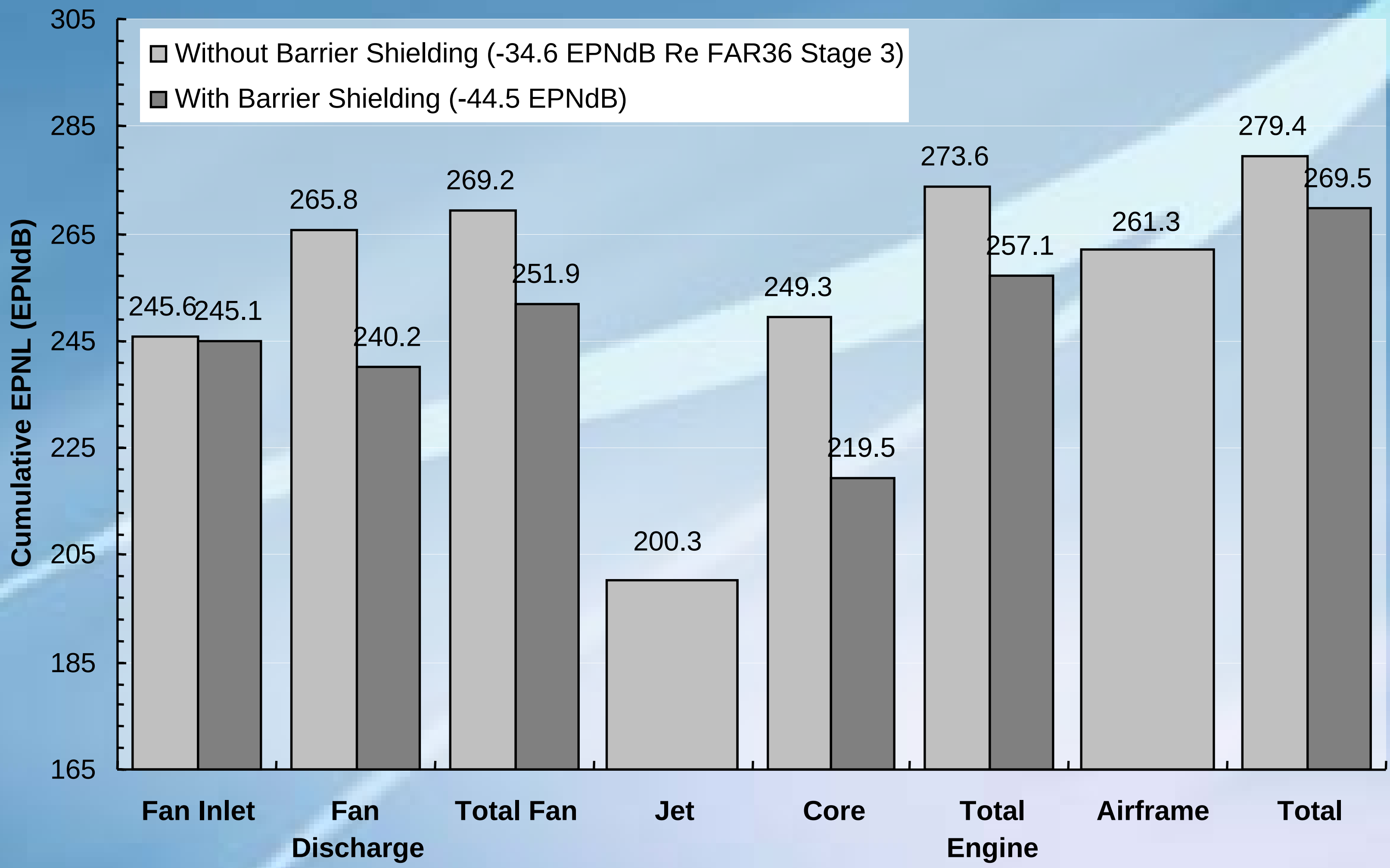
Community EPNLs



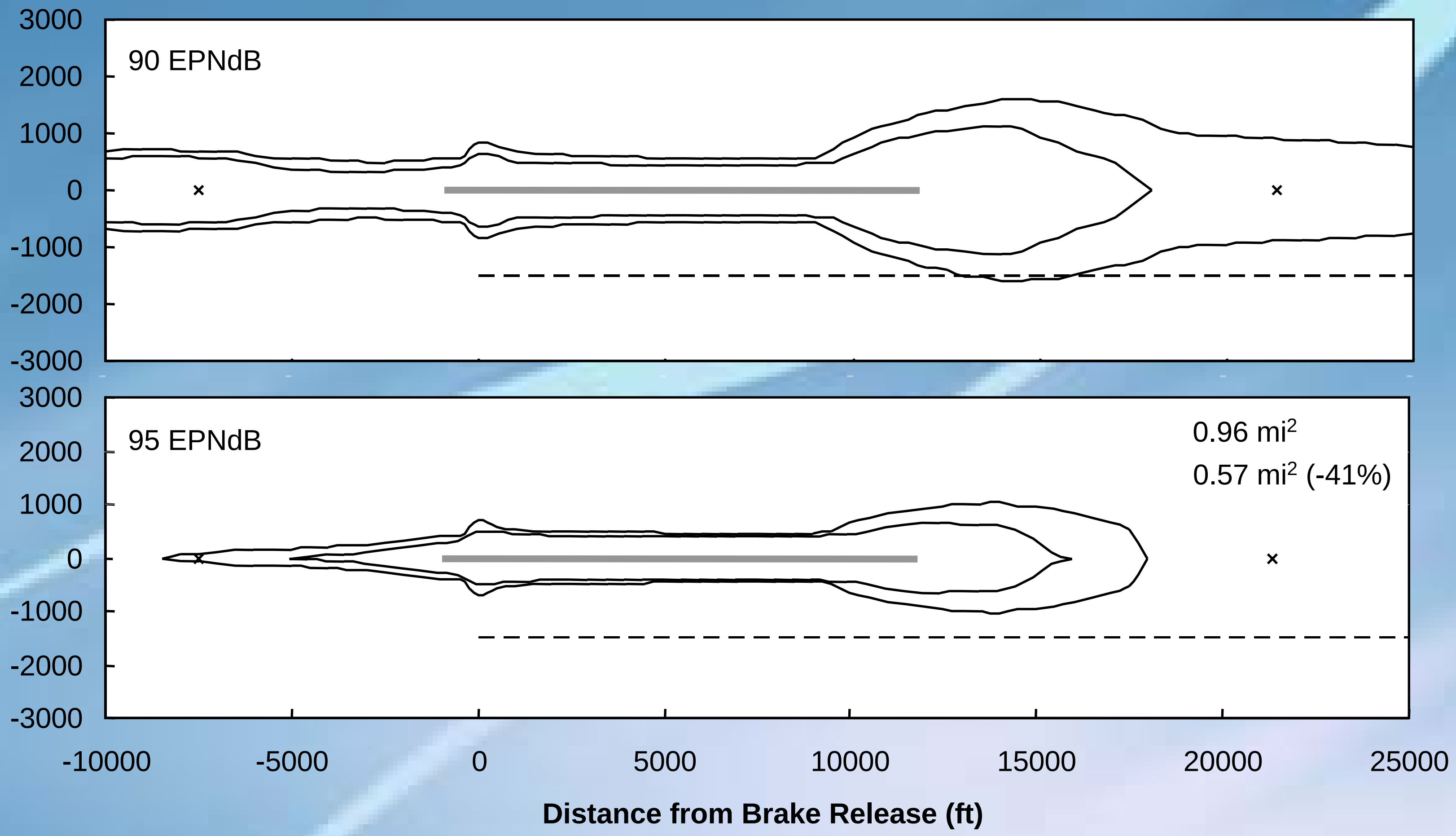
Approach EPNLs



Cumulative EPNLs



EPNL Contours



Summary

♦ Noise of advanced turbofan engines is effectively shielded by wing insertion loss:

⇒ Dominance of fan discharge noise
⇒ Low levels of distributed jet noise

♦ Over-the-wing engine mounting will result in additional noise reduction not considered in this study:

⇒ Low frequency boundary layer entrainment noise between wing and nacelle
⇒ Underwing high frequency noise reflection

♦ Relative dominance of airframe noise, especially with wing insertion loss