Fan Broadband Noise Generation and Suppression

AVIATION 2015

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Outline

- Introduction to Fan Noise
- Generation Mechanisms
- Suppression Techniques
- Summary

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Much of the data presented here is from NASA wind tunnel tests and FAA databases. Engine and fan noise data are company proprietary and not publicly available.

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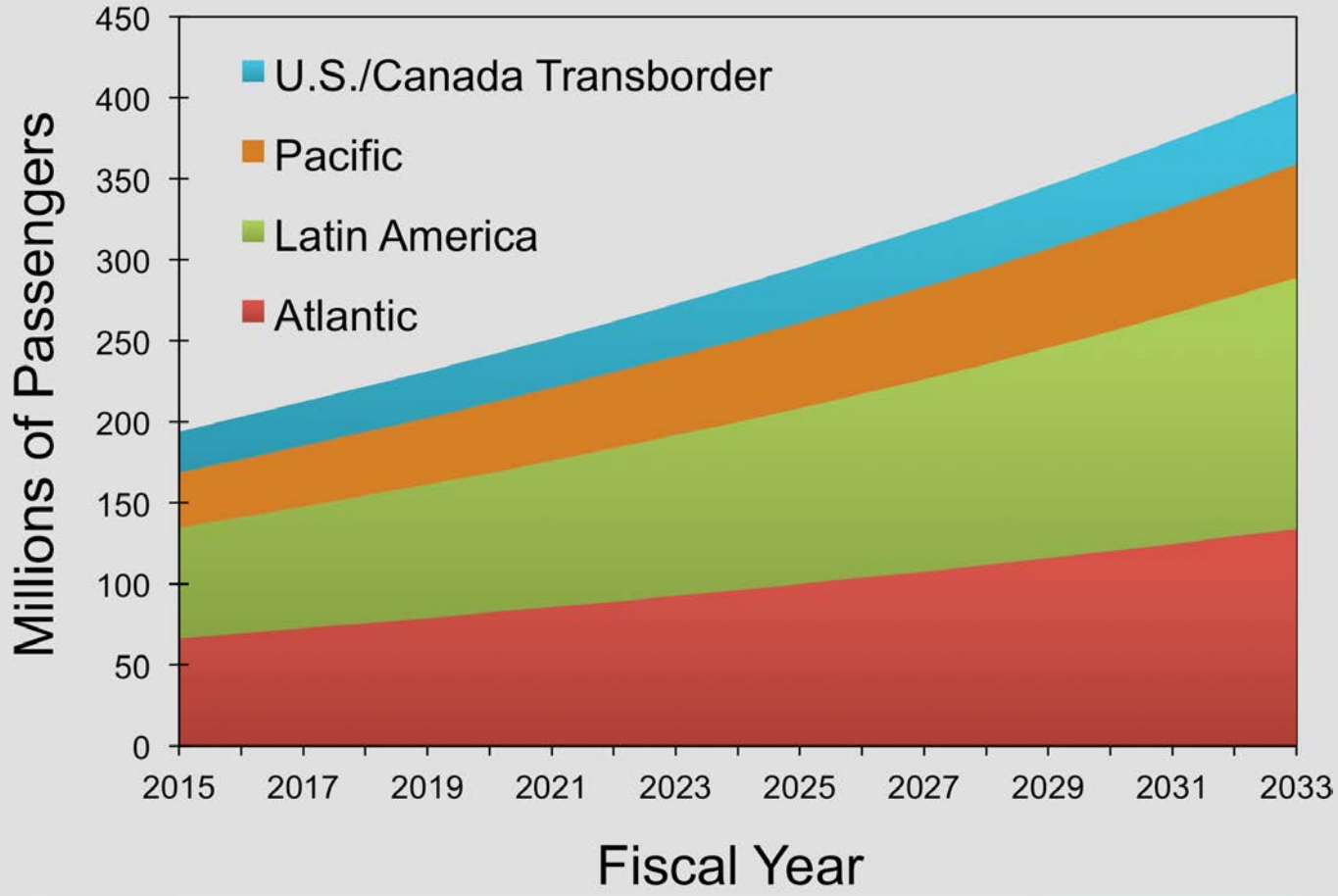
Noise data are presented here using a variety of metrics including sound pressure level (SPL) spectra, sound power level (PWL) spectra, and Effective Perceived Noise Level (EPNL).

Motivation

Aircraft noise has an adverse effect on the environment and as a result it is regulated.

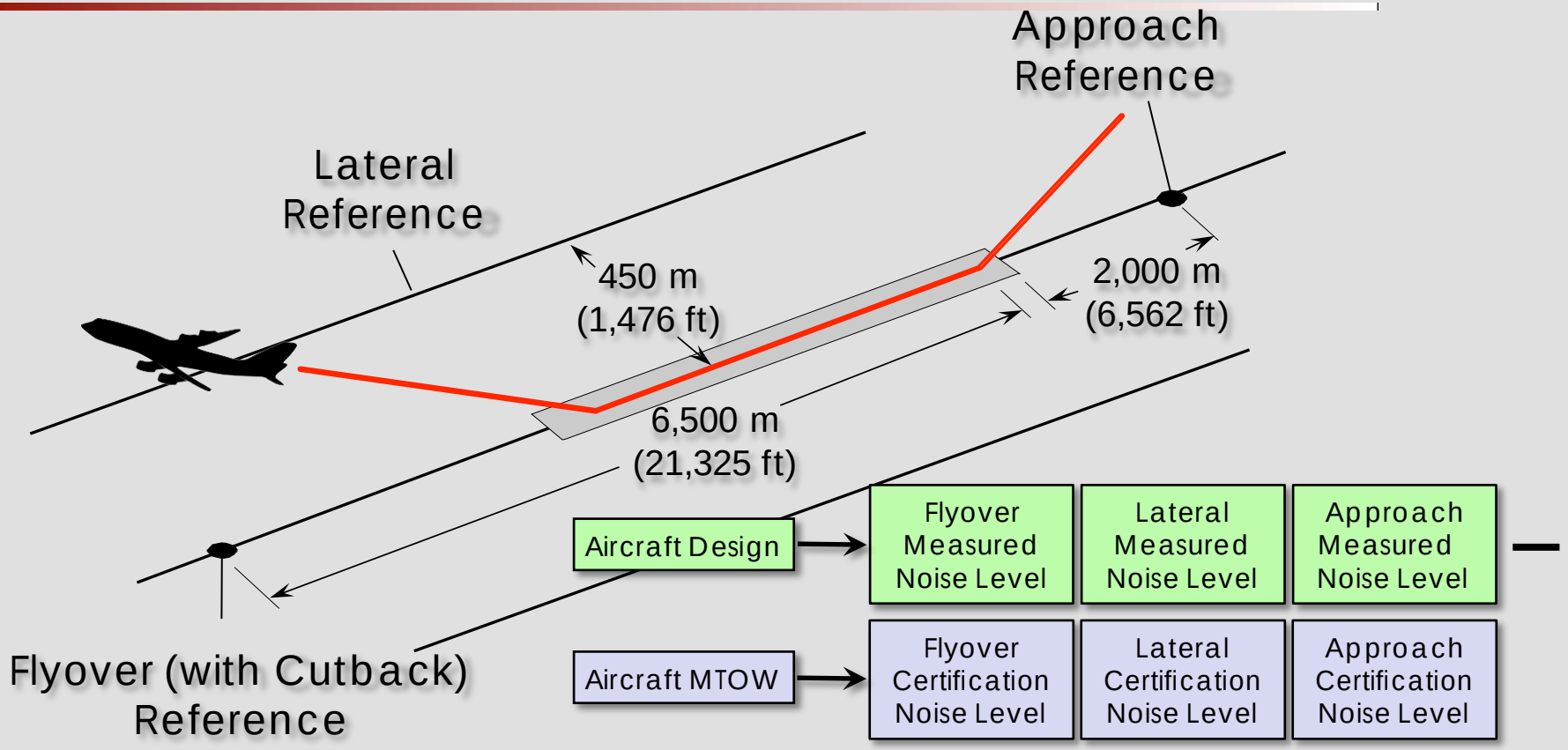
A Growing Problem

Projected growth of passenger traffic in the U.S.



Source: FAA Report

Community Noise Metric

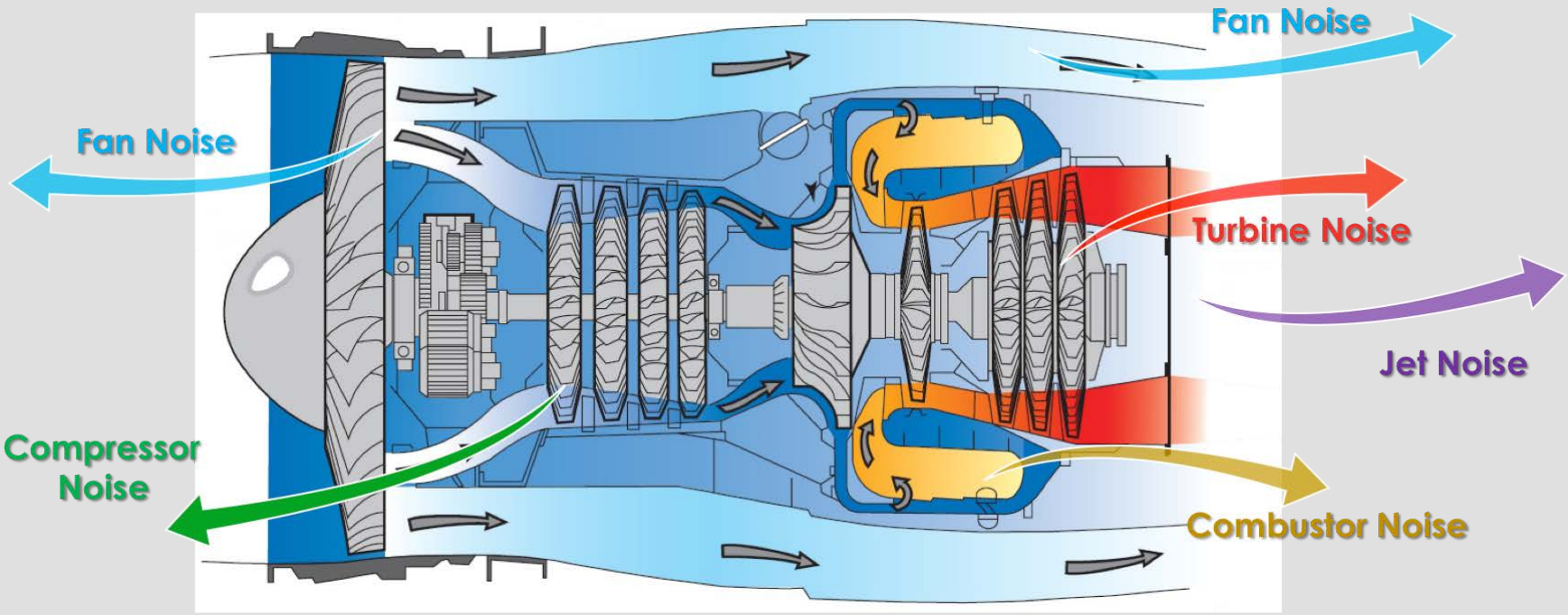


Aircraft Design →	Flyover Measured Noise Level	Lateral Measured Noise Level	Approach Measured Noise Level
Aircraft MTOW →	Flyover Certification Noise Level	Lateral Certification Noise Level	Approach Certification Noise Level
Noise Margin →	Flyover Noise Margin	Lateral Noise Margin	Approach Noise Margin

Cumulative noise (CUM) margin is the sum of the individual margins.
(Airbus 380-842 CUM Margin = 16.4 EPNdB)

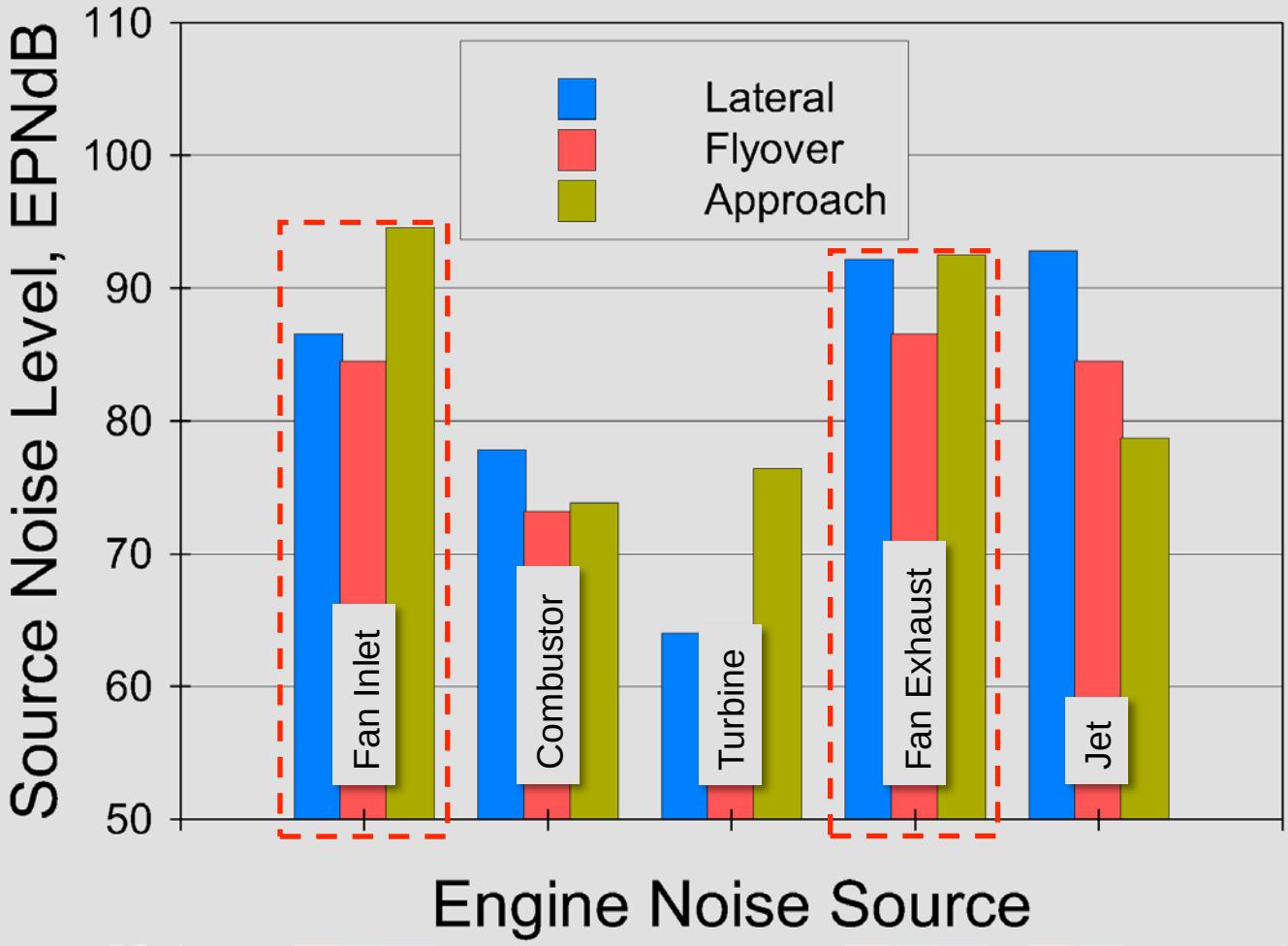
Engine Noise Sources

Fan is one of the several engine noise sources.



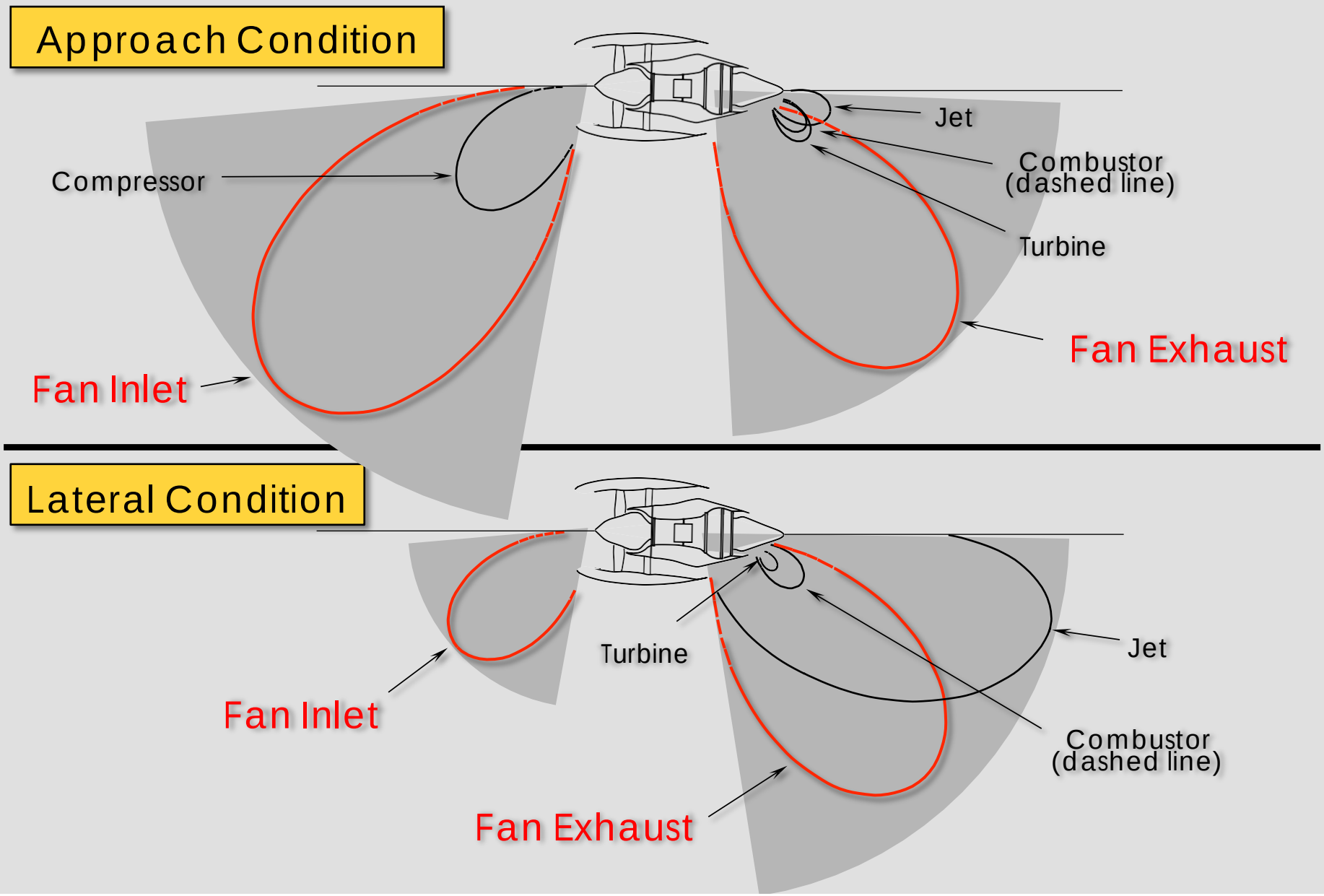
Engine Source Levels

Fan is a significant contributor to the overall engine noise emissions.



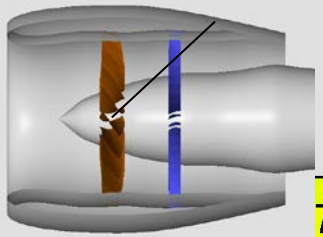
Estimated Source Level Breakdown for a High Bypass Ratio Turbofan

Directivity of Fan Noise



Characteristics of Fan Noise

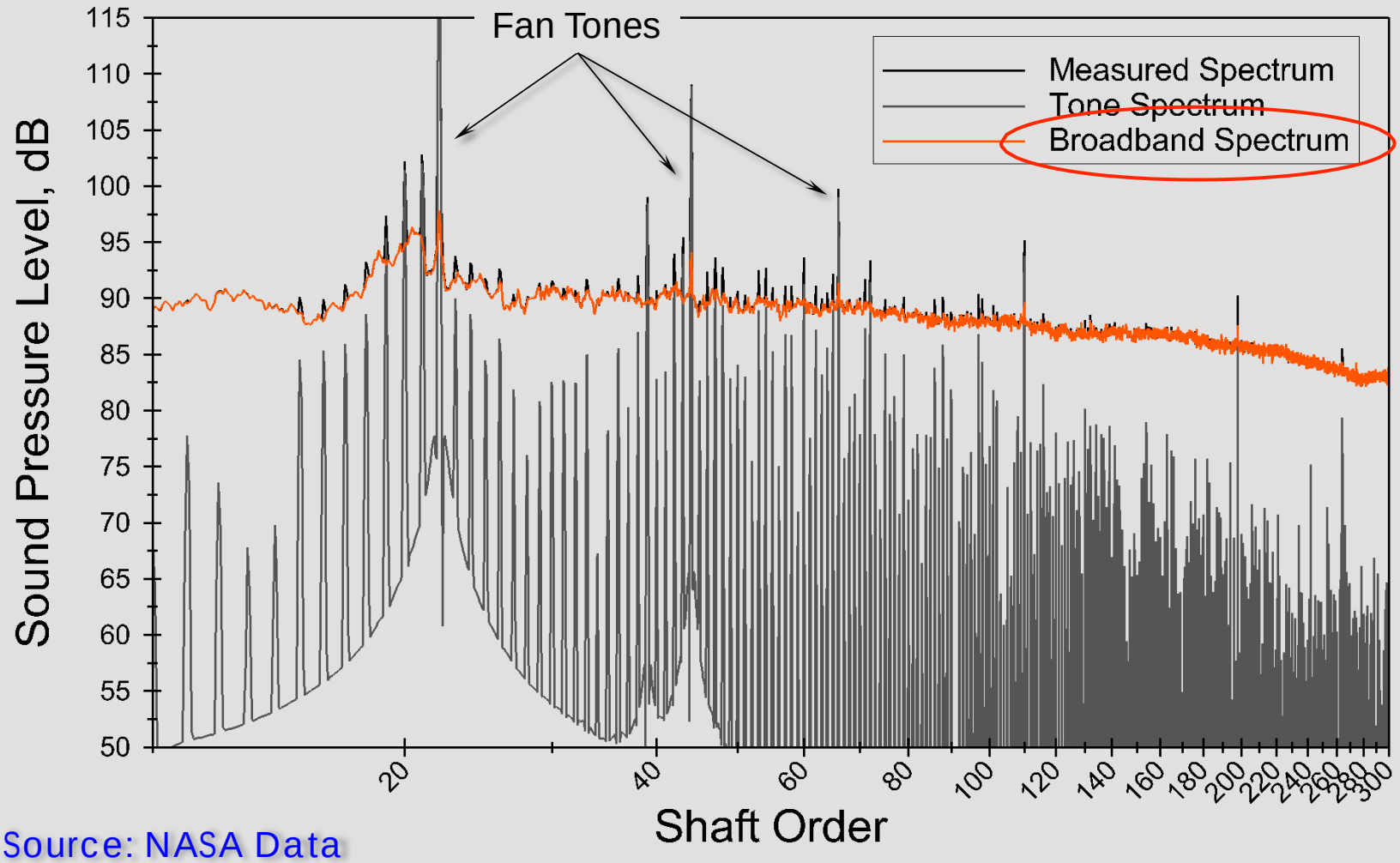
Fan noise has rich content and characteristics.



Source: NASA Data

Spectral Content of Fan Noise

Fan broadband noise is the non-tonal component of the spectrum (i.e., part not coherent to the fan shaft rate).



Source: NASA Data

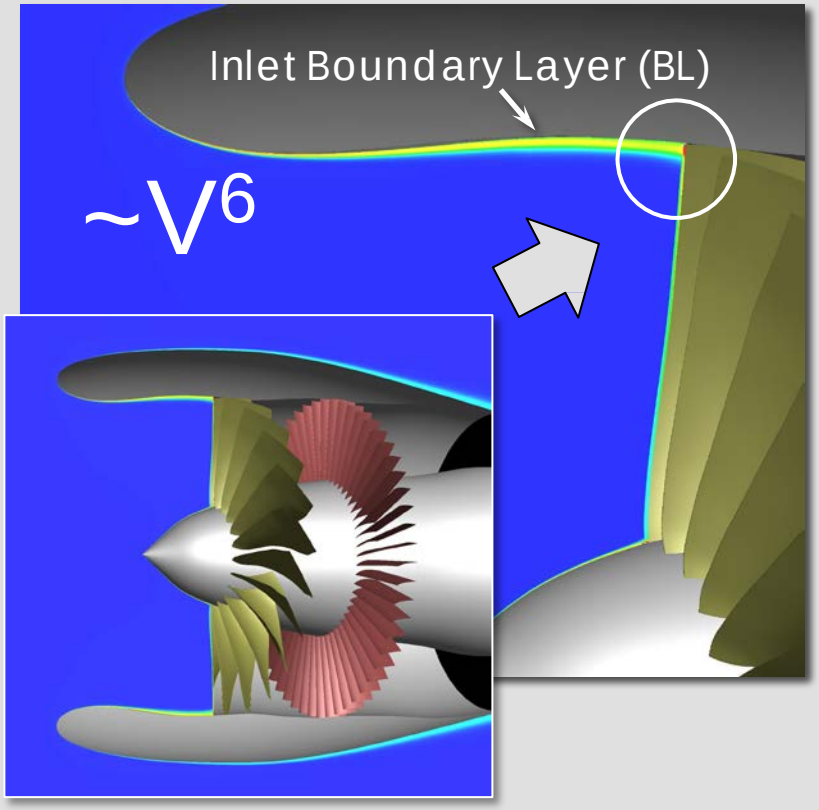
Fan Broadband Noise

- Fan noise is principally produced as a result of unsteady flow perturbations interacting with the fan blades and the outlet guide vanes.

- Fan broadband noise is generated by the interaction of flow turbulence with the blades and vanes.

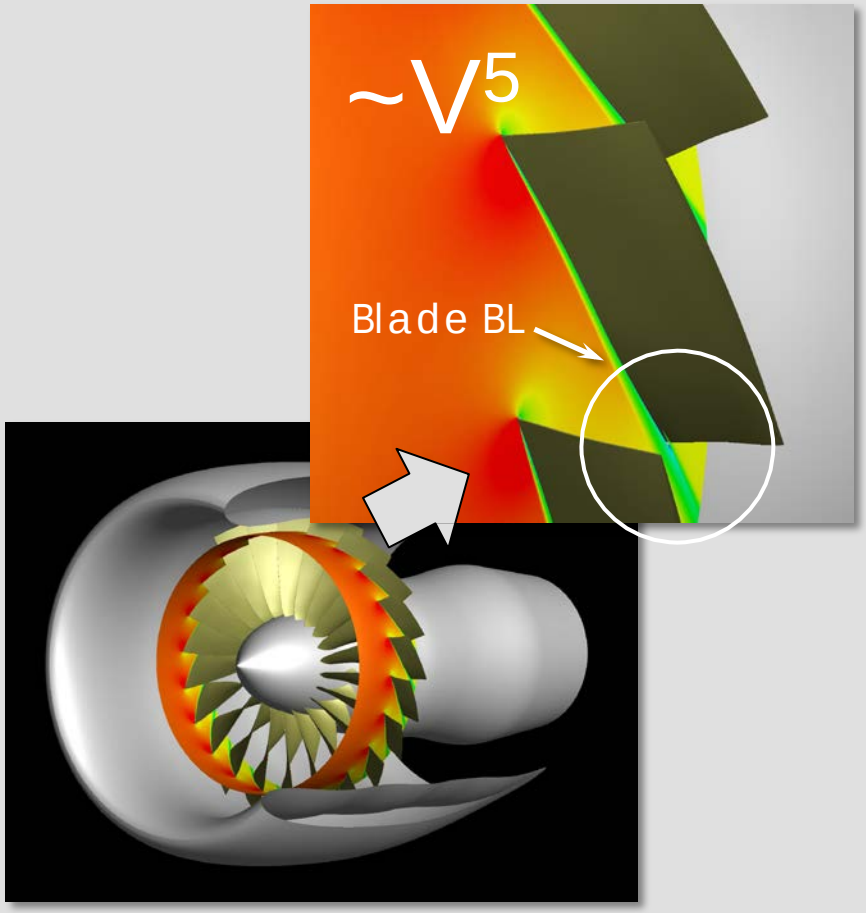
- Important sources of fan broadband noise include ...

Rotor Sources



Inlet BL turbulence is scattered into sound by the rotor blade tips.

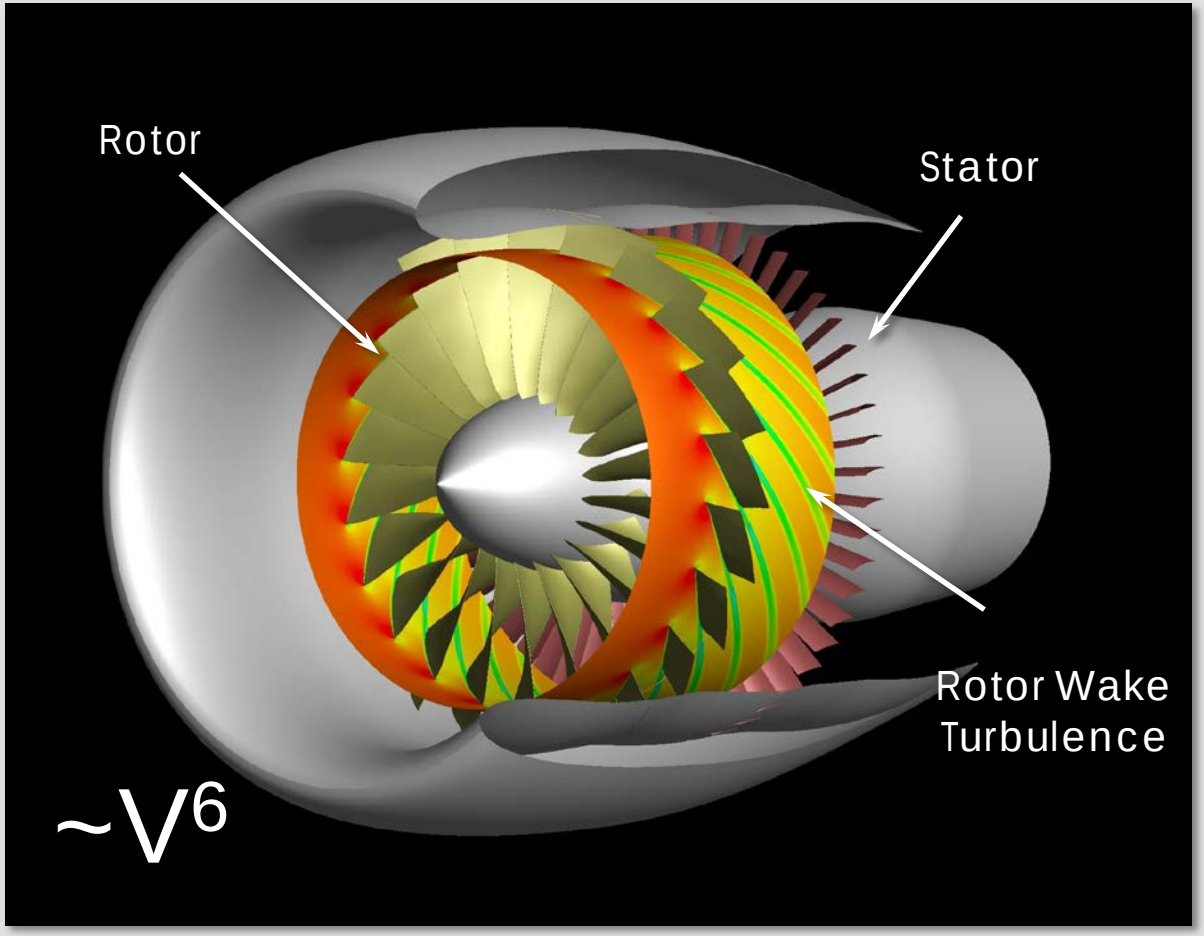
Inlet turbulence impinging on the blades is another noise source.



Blade BL turbulence is scattered into sound at the trailing edge.

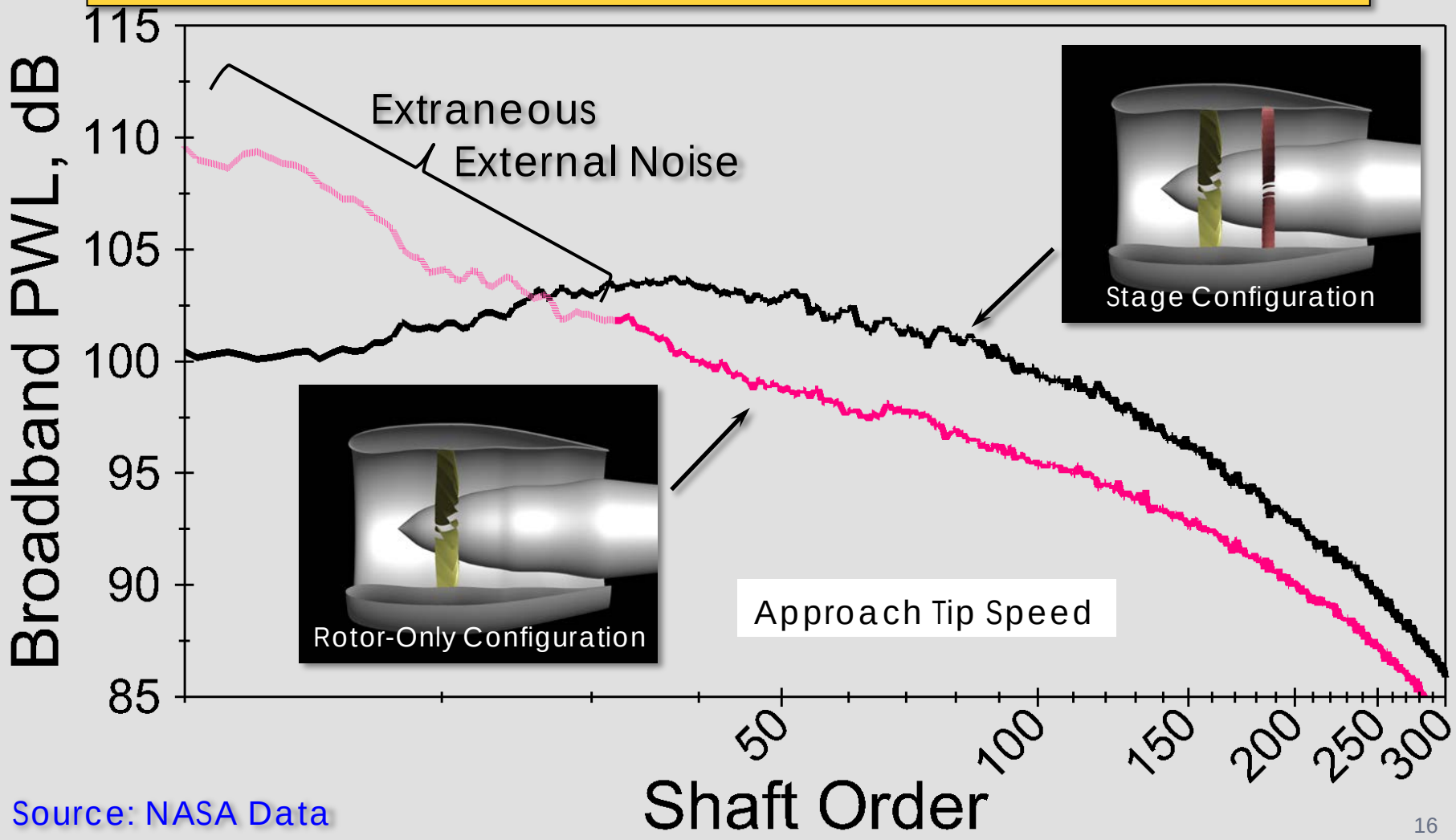
Rotor / Stator Interaction Source

The principal source of fan broadband noise is the interaction of rotor wake turbulence with the fan exit guide vanes.



Source Hierarchy

Generally rotor/stator interaction noise is more important than rotor self-noise though the latter should not be ignored.



Source: NASA Data

Effect of Rotor Transmission

- Inlet/exhaust power noise split is partly governed by the rotor acoustic transmission which is controlled by the rotor geometry and flow swirl downstream of the rotor …

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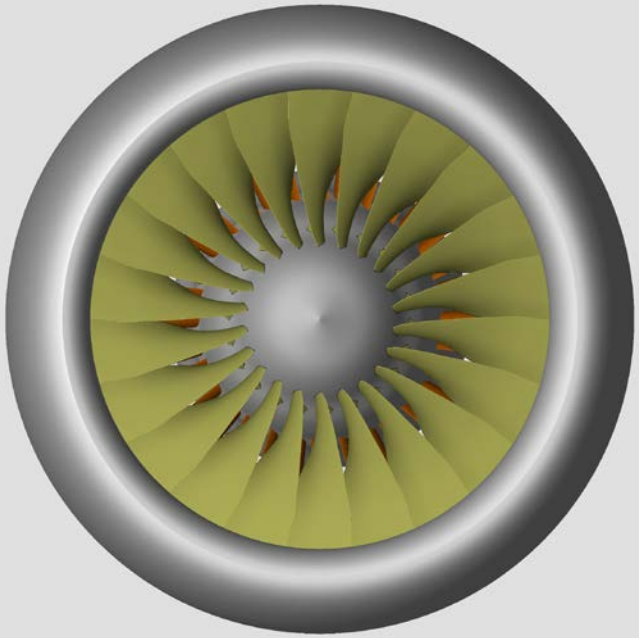
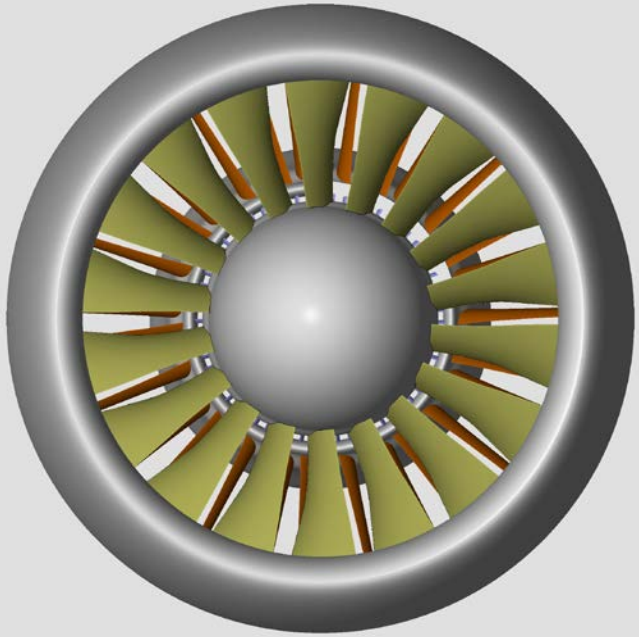


Moderate Blade Count Fan

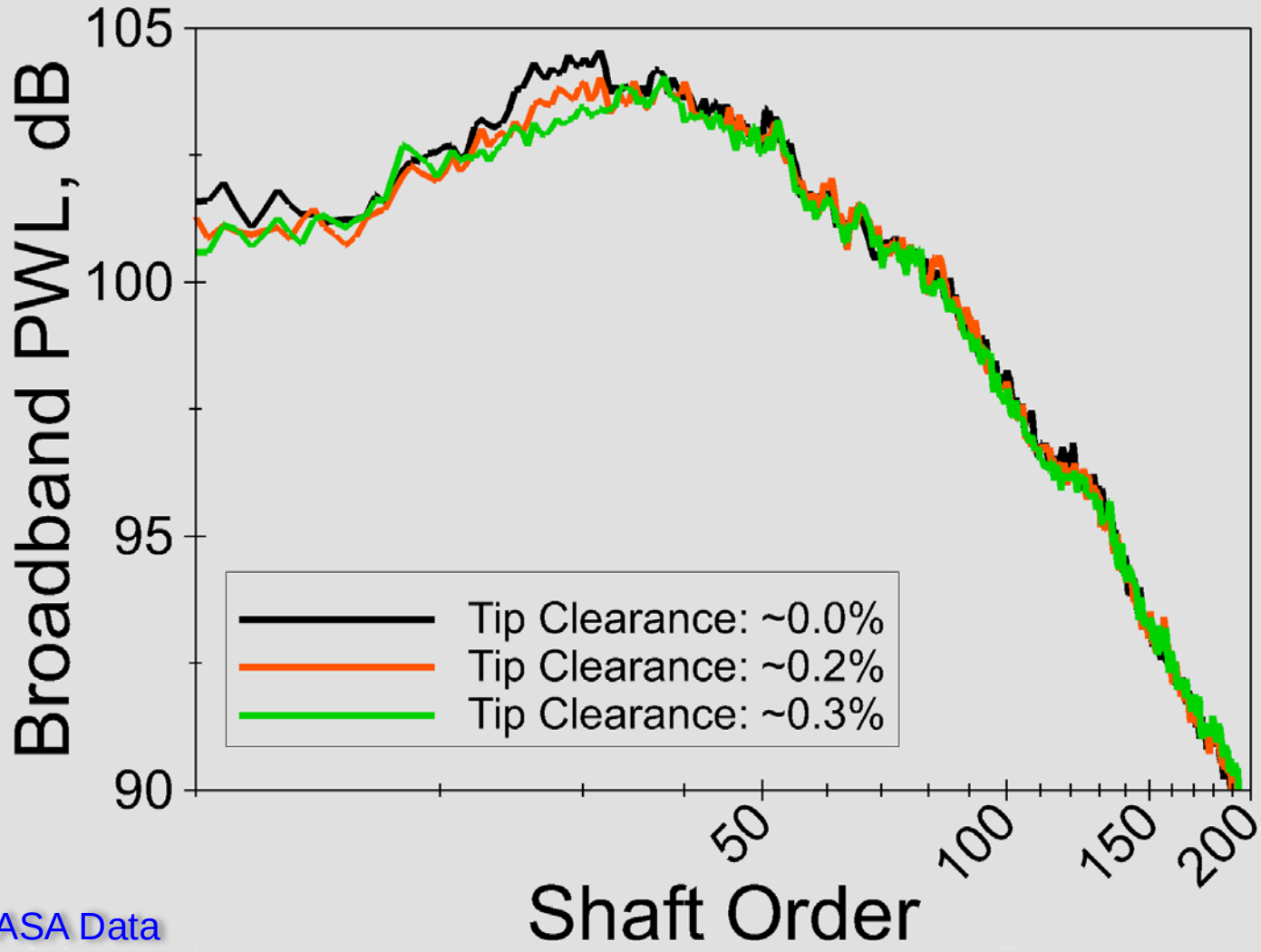


Low Blade Count Fan

As the rotor blade count decreases, swirl becomes the primary barrier against the rotor acoustic transmission.

Effect of Tip Clearance

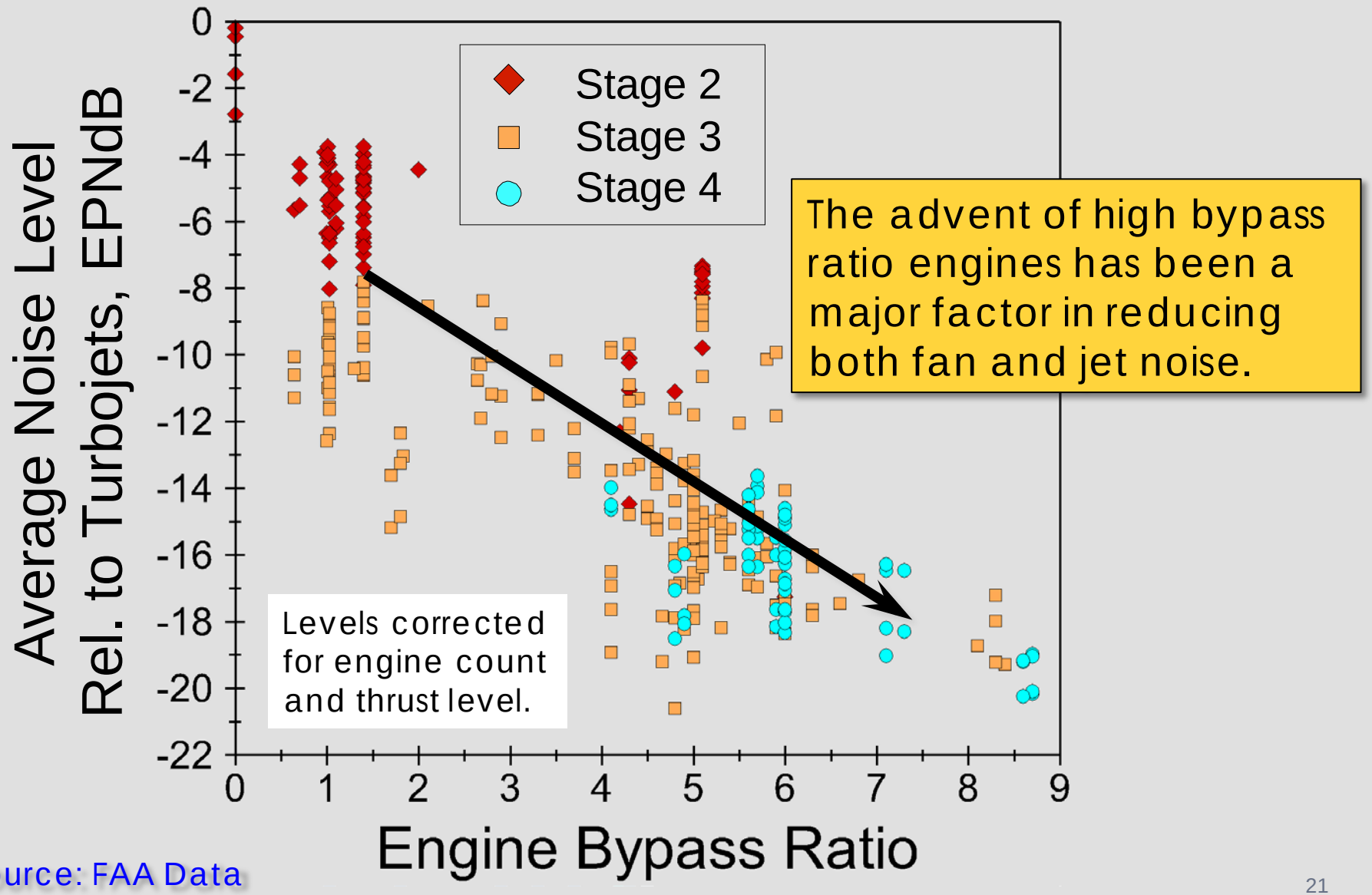
Tip gap does not have a significant influence on noise.



Source: NASA Data

Noise Mitigation

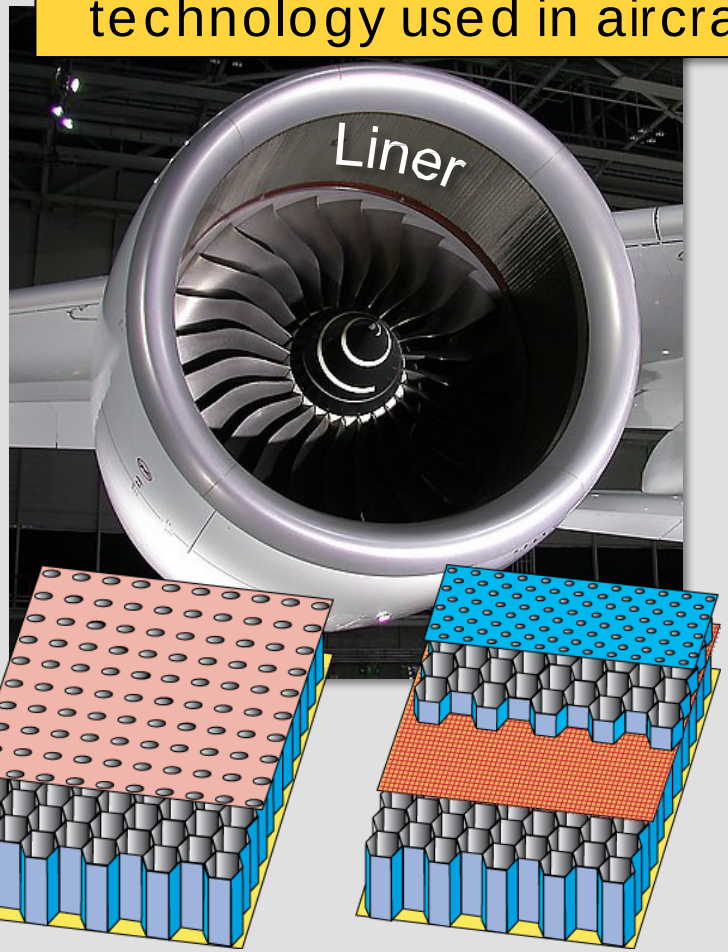
Cycle Change



Source: FAA Data

Liners

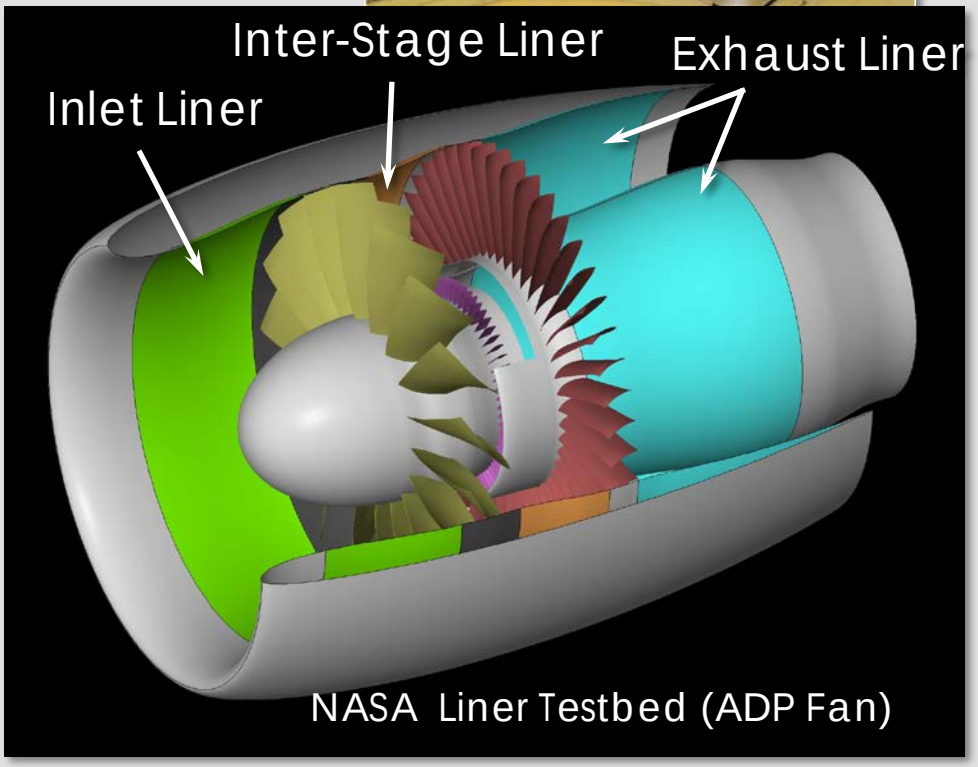
Acoustic liner is a common noise reduction technology used in aircraft engines today.



Single Degree of Freedom (SDOF)

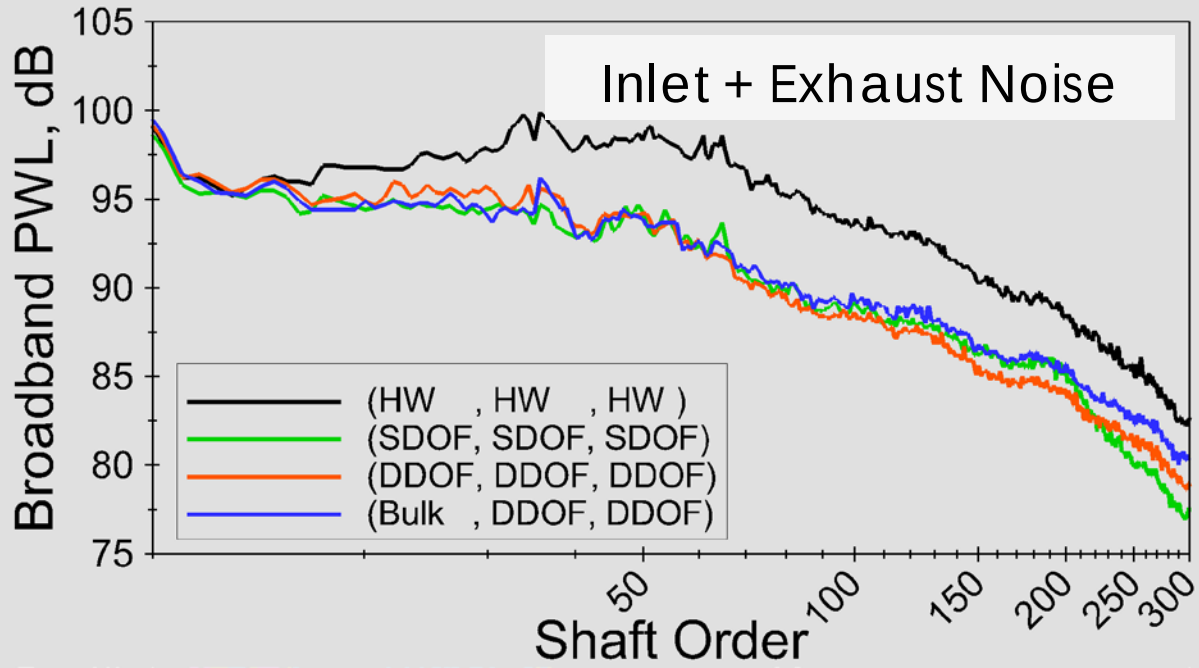
Double Degree of Freedom (DDOF)

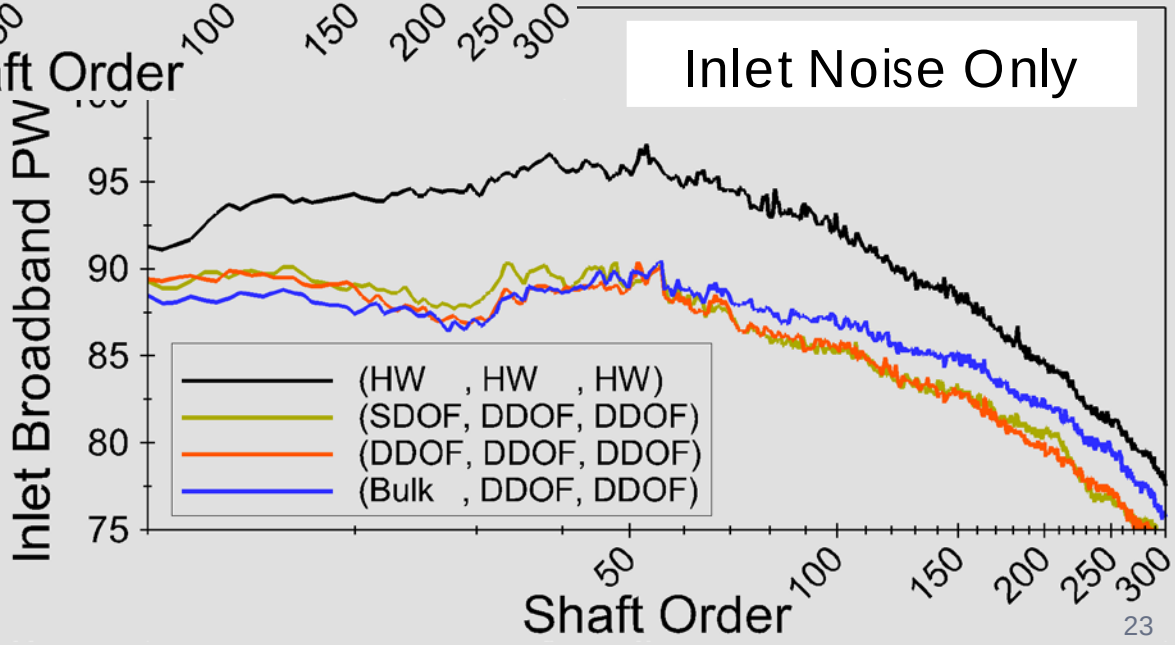
NASA ADP Fan Rig



NASA Liner Testbed (ADP Fan)

Liner Impact

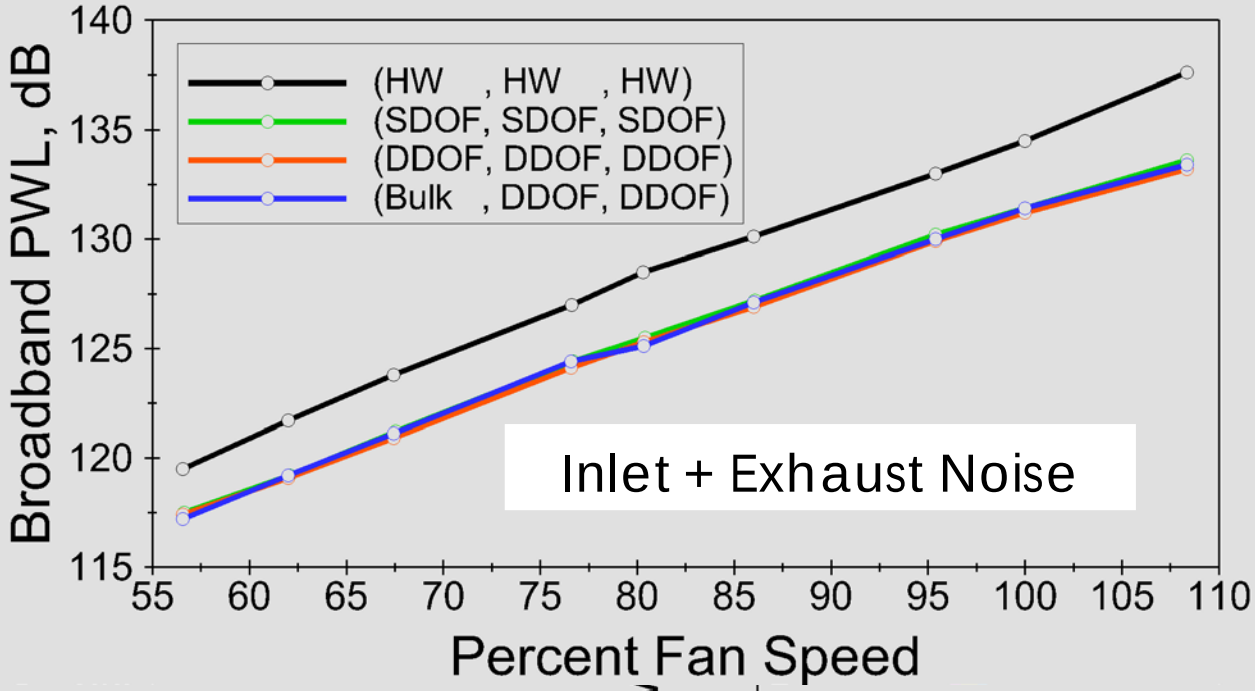


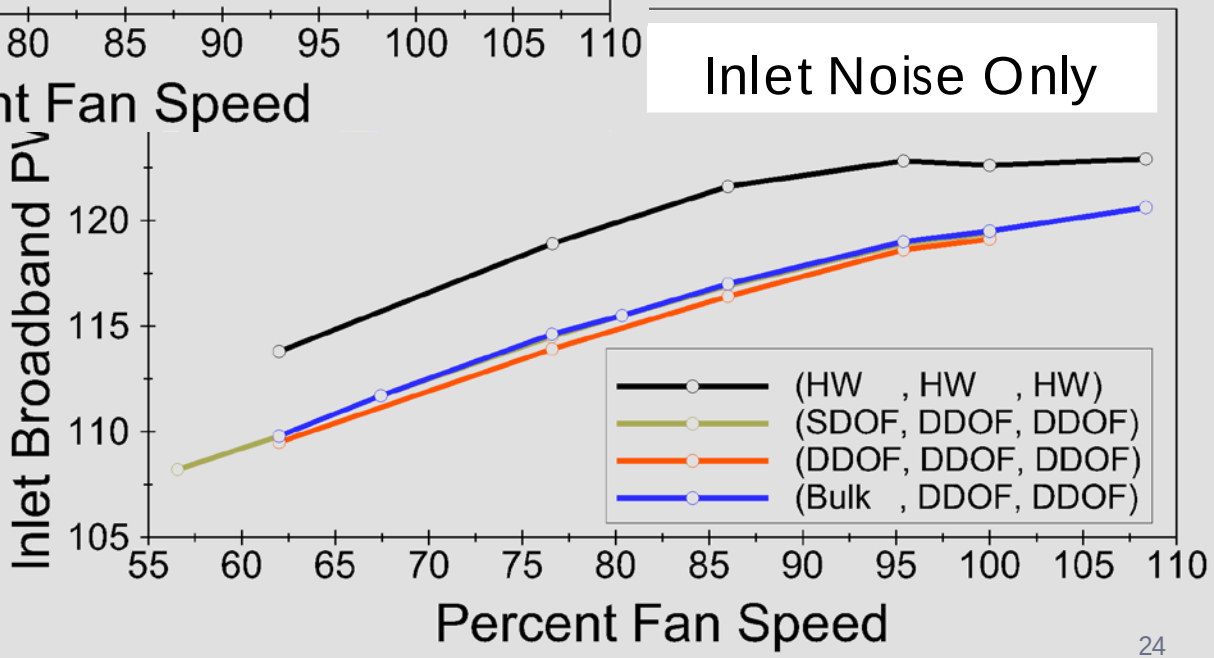


Overall, no significant difference was seen in the performance of SDOF, DDOF, and Bulk liners over a wide range of frequencies.

Source: NASA Data

Liner Impact (Cont'd)





Substantial noise reduction can be achieved using liners over a wide range of frequencies and tip speed conditions.

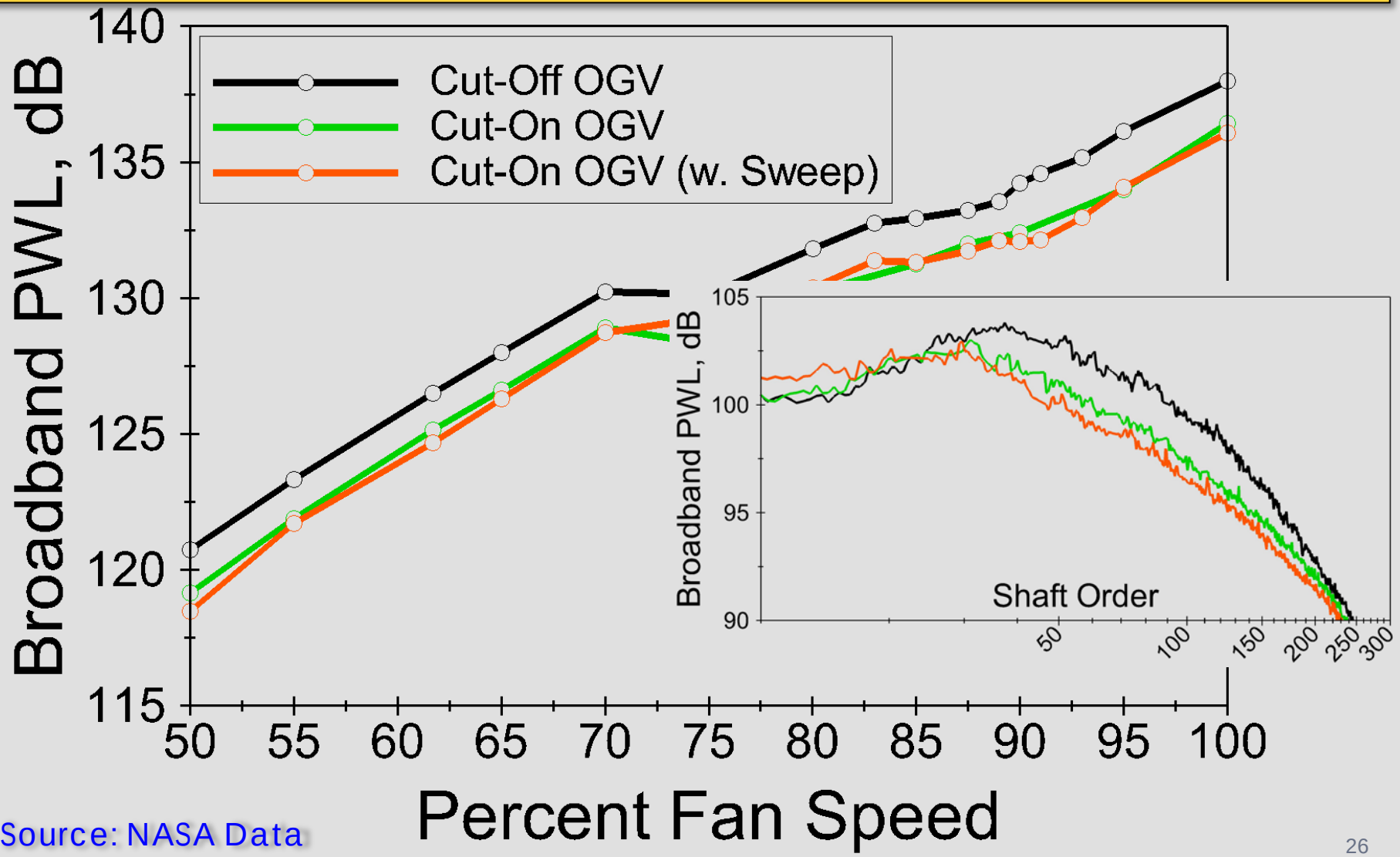
Vane Count

Reduce Broadband Noise

Reduce Tone Penalty

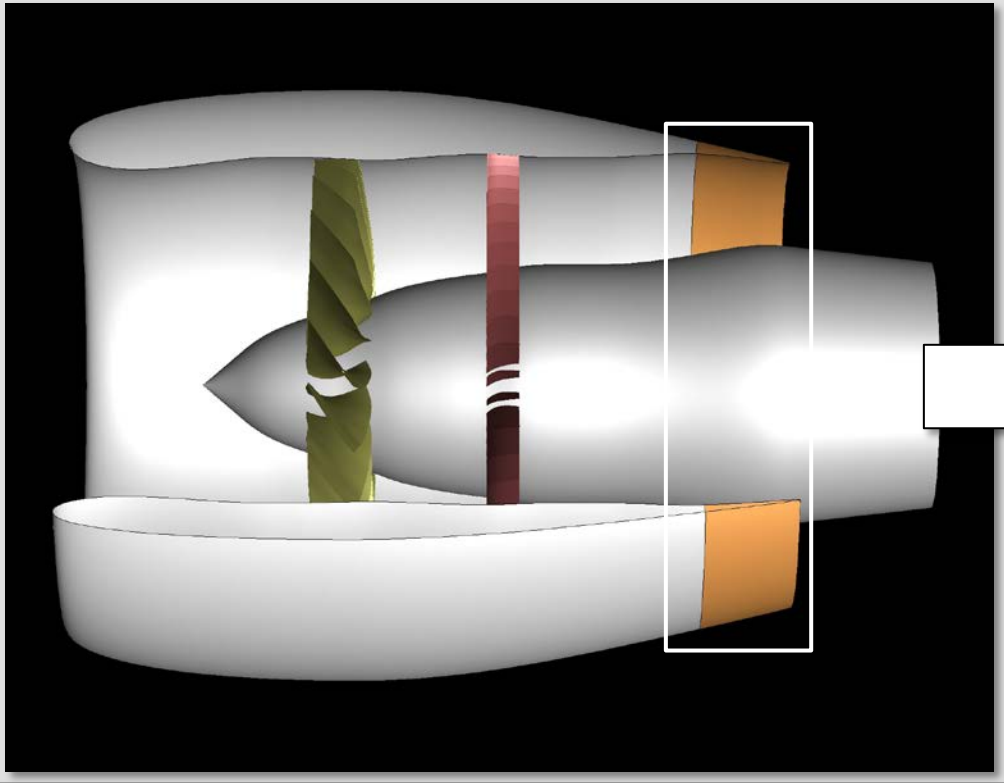
Vane Count Impact

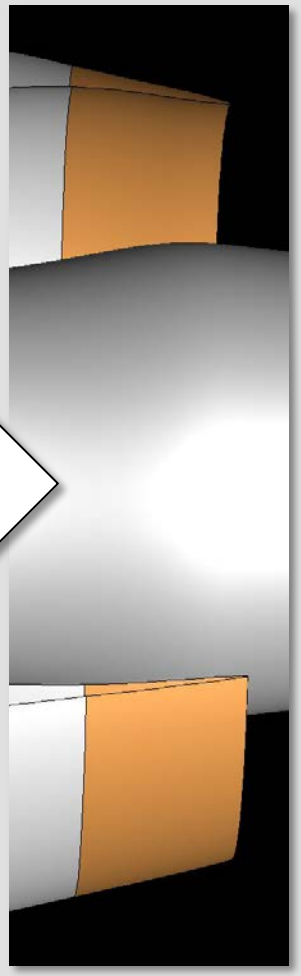
Vane count reduction can reduce R/S interaction broadband noise.

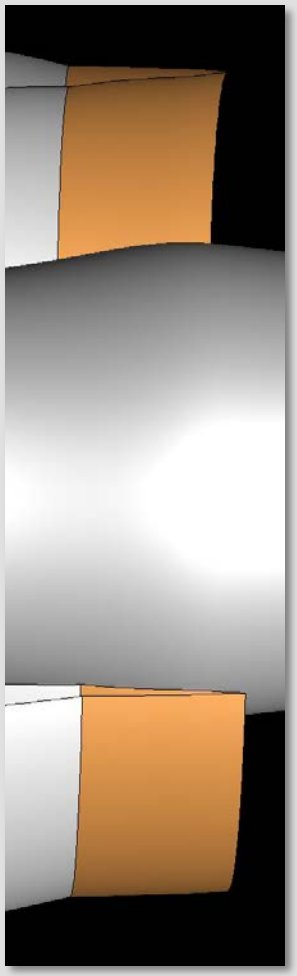


Source: NASA Data

Variable Area Nozzle (VAN)







Operating the fan close to its highest efficiency point at each tip speed should reduce fan noise by improving flow incidence on the fan blades.

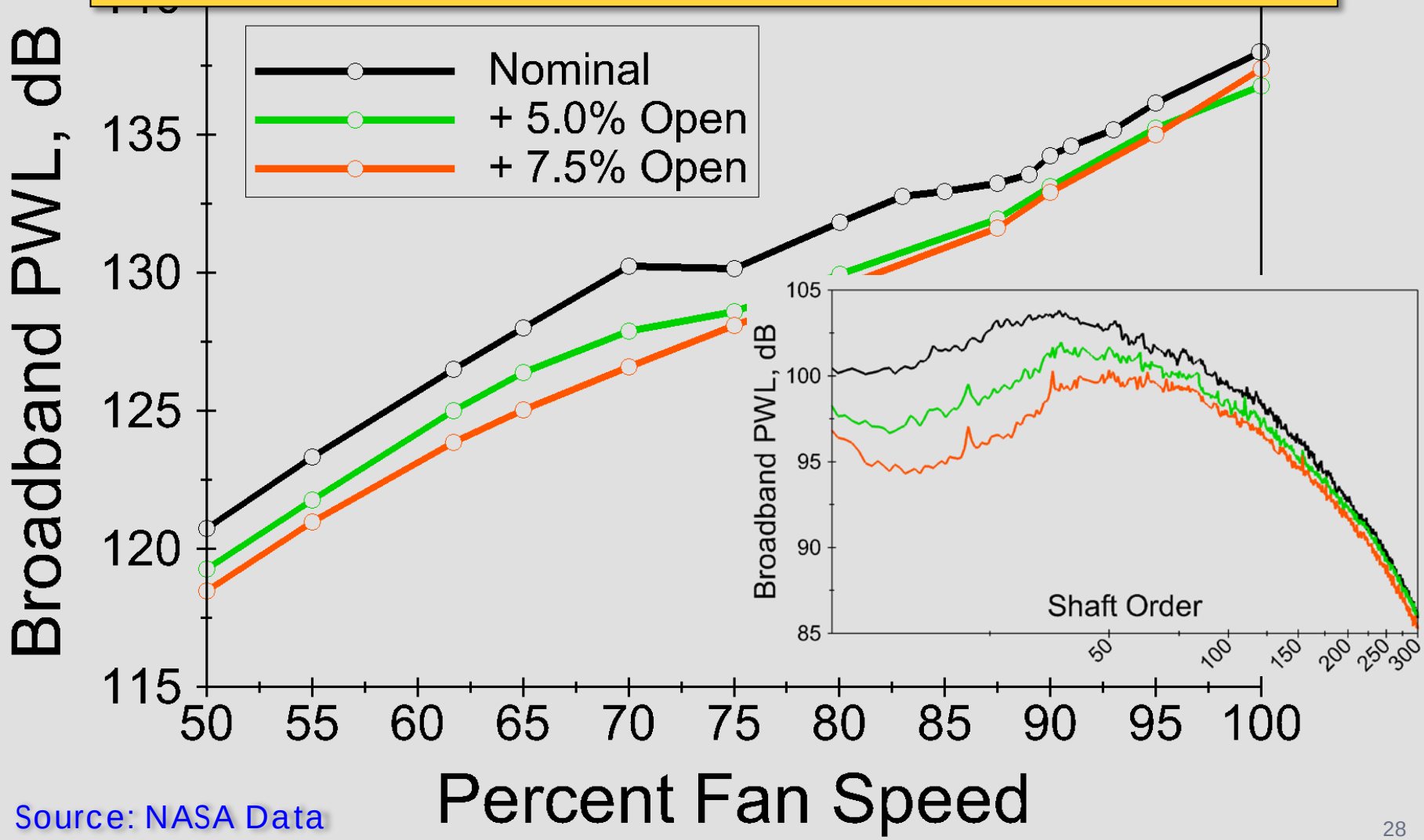
Nominal Nozzle

Open Area Nozzle*

* Open area exaggerated for illustration purposes.

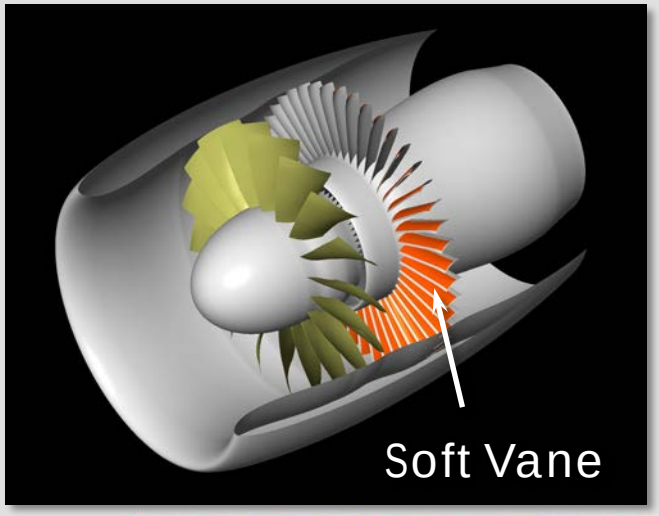
VAN Impact

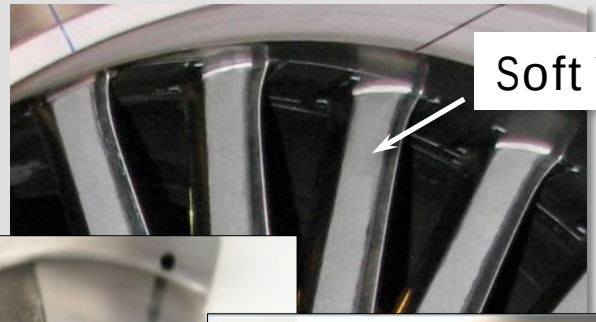
Broadband noise level reductions were measured for all fan operating conditions over a wide range of frequencies.

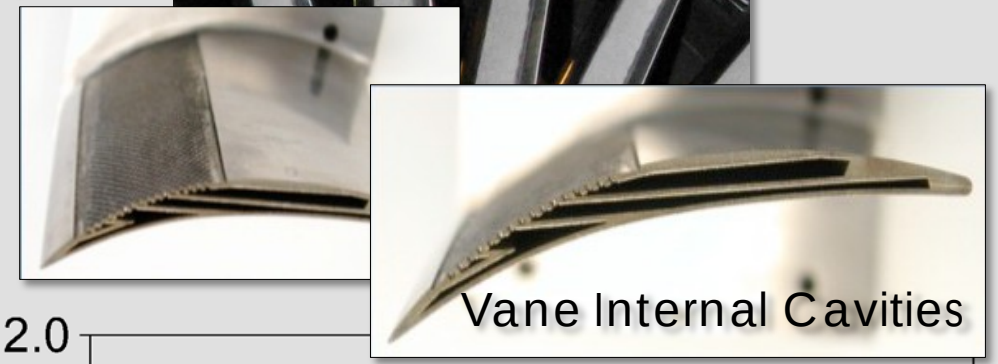


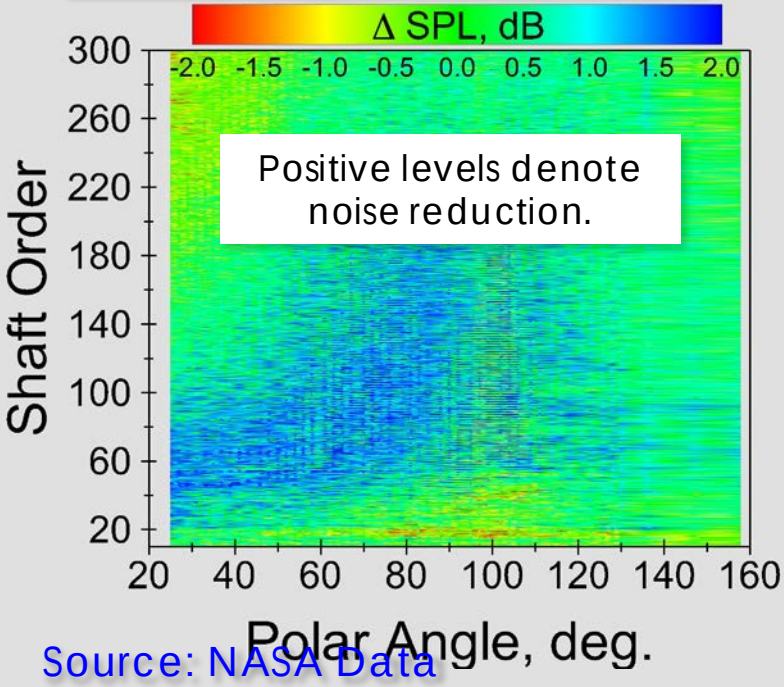
Source: NASA Data

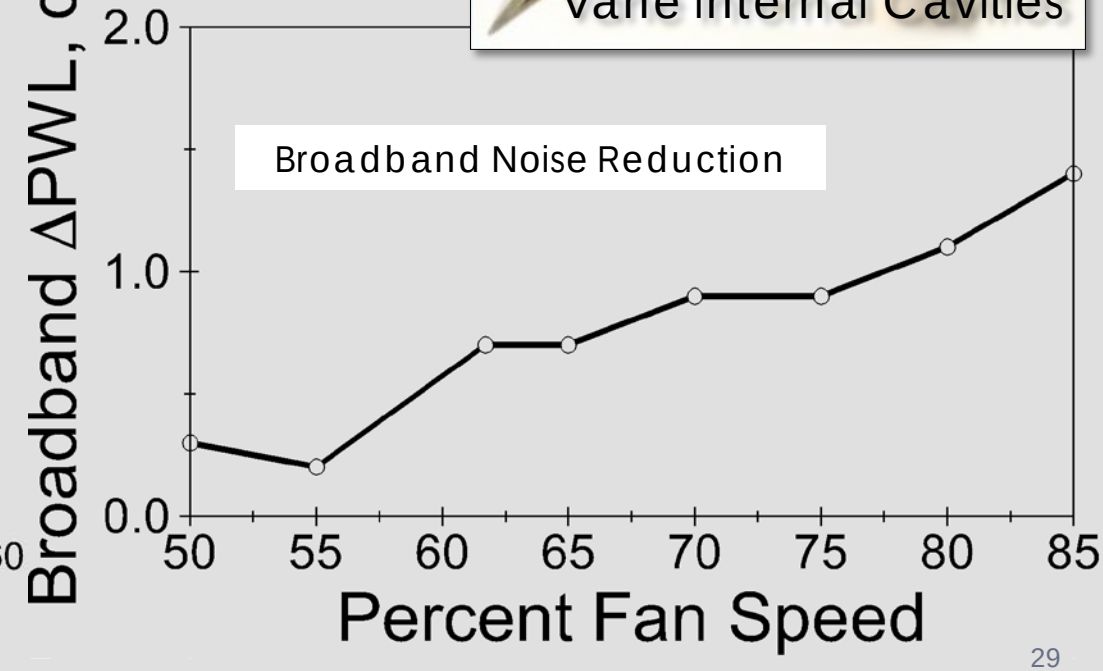
Soft Vane





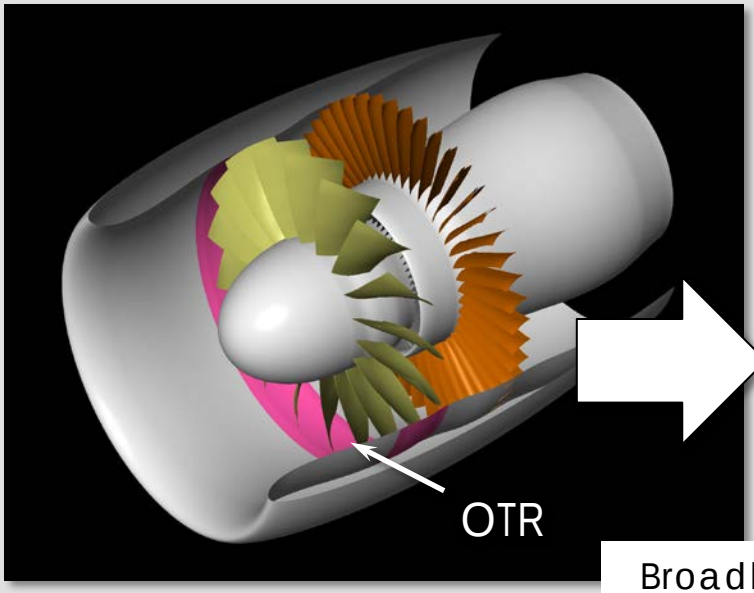


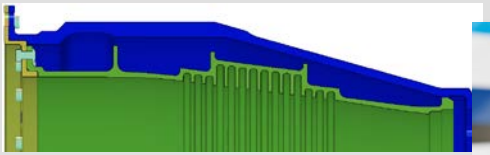




Source: NASA Data

Over-The-Rotor (OTR) Treatment

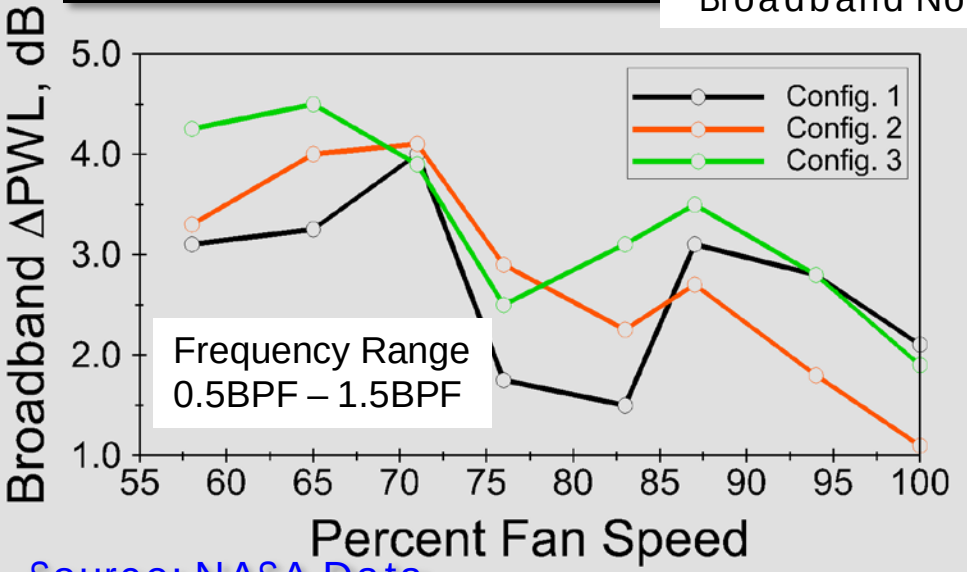


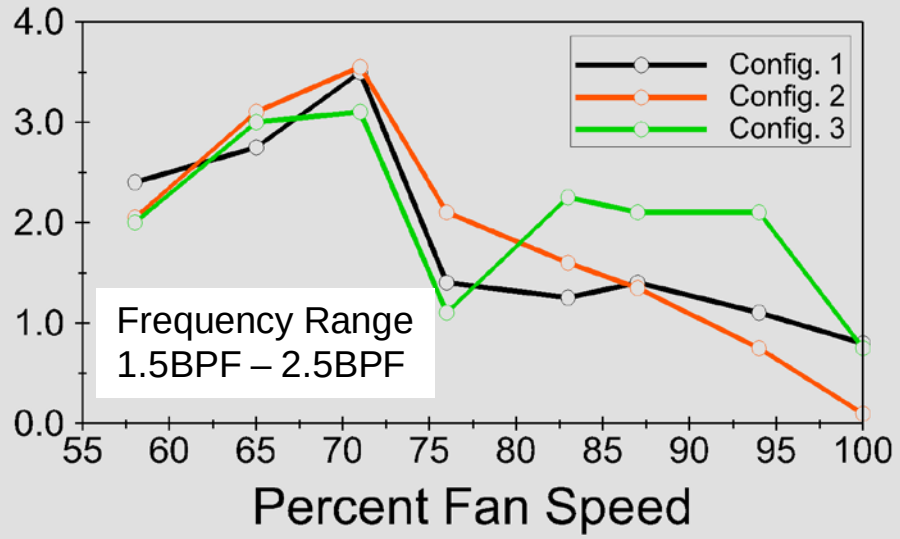


Standard Fan Case

OTR-Treated Fan Case

Broadband Noise Reduction





Source: NASA Data

Concluding Remarks

- Fan is an important source of aircraft engine noise whose importance is likely to grow with increasing engine bypass ratio.
- A better understanding of its source mechanisms and scaling laws should provide deeper insight for devising methods for mitigating it.
- Noise reduction benefits drawn from cycle change will likely reach a plateau requiring more reliance on noise reduction technology.
- More innovative noise reduction techniques may have to be brought to bear to make substantial breakthroughs in reducing fan broadband noise.

Questions?