



**CAEP  
WG1**

***Continuing Work on Aircraft Noise Reduction***  
***Summary of the Aircraft Noise  
Technology Workshop***  
***(São Paulo, December 3rd, 2001)***

**AIRPORT NOISE SYMPOSIUM**

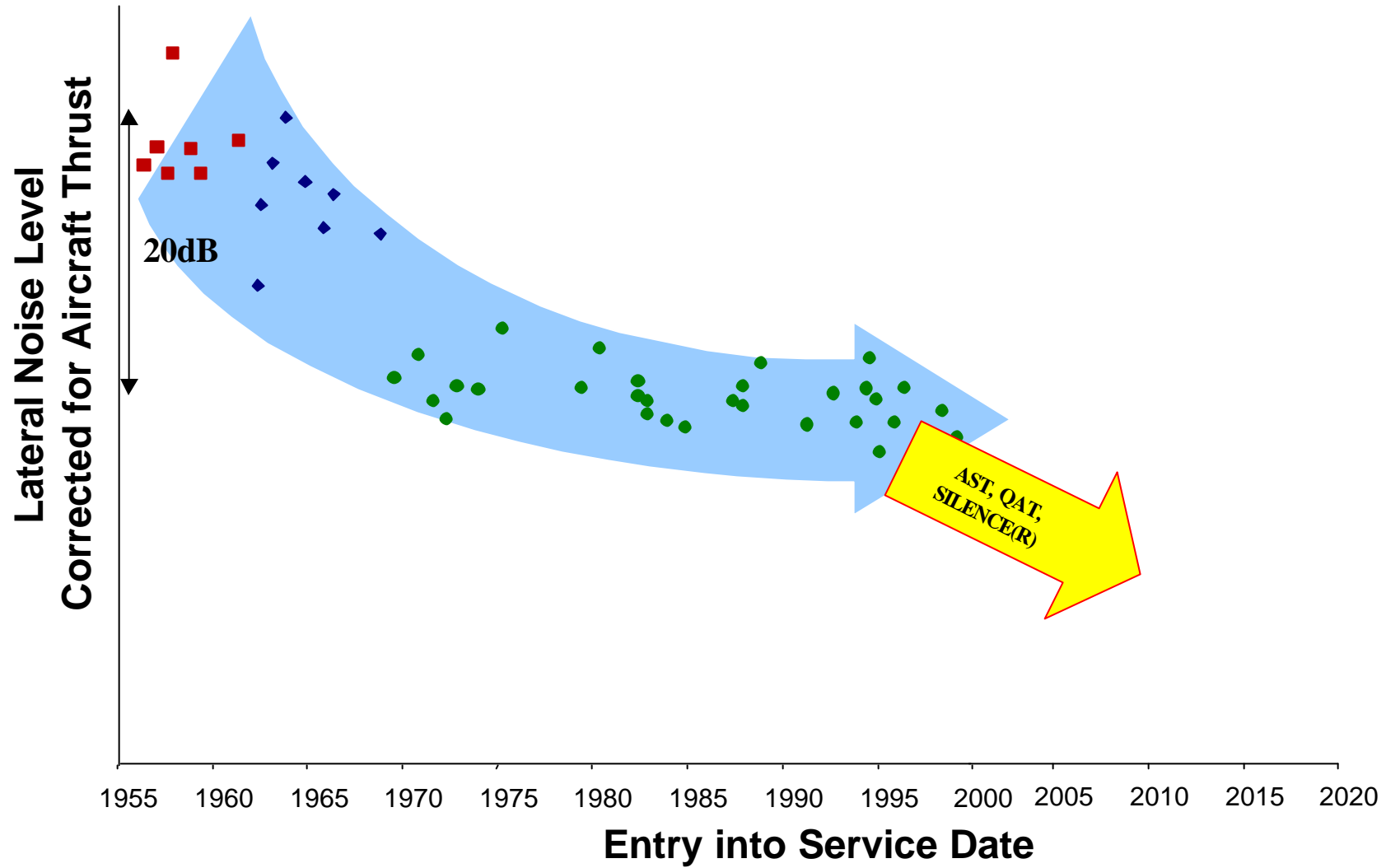
**San Diego, February 26th, 2002**

**Ira Rushwald**

**Manager, Noise Engineering – The Boeing Company**



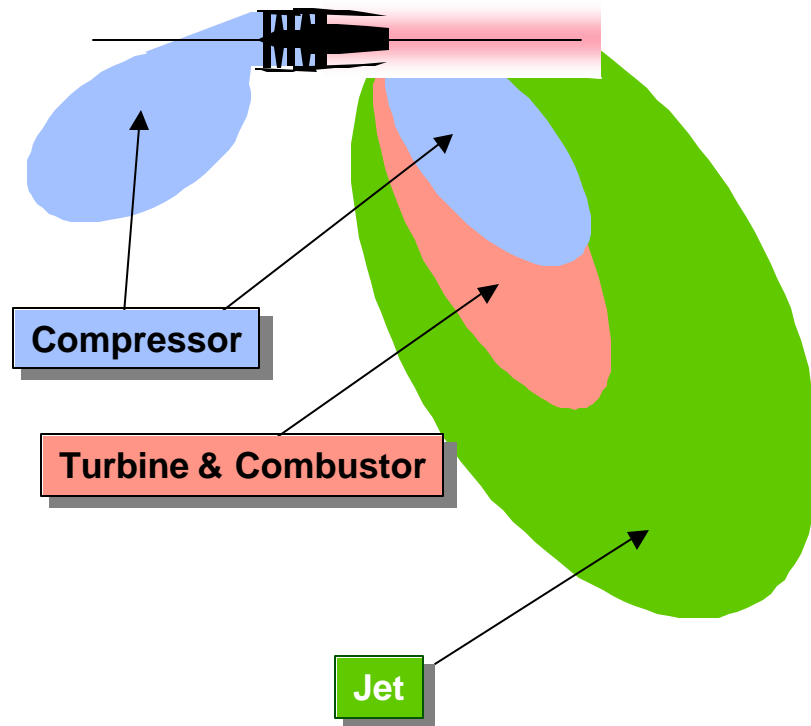
# Noise Research Program Targets





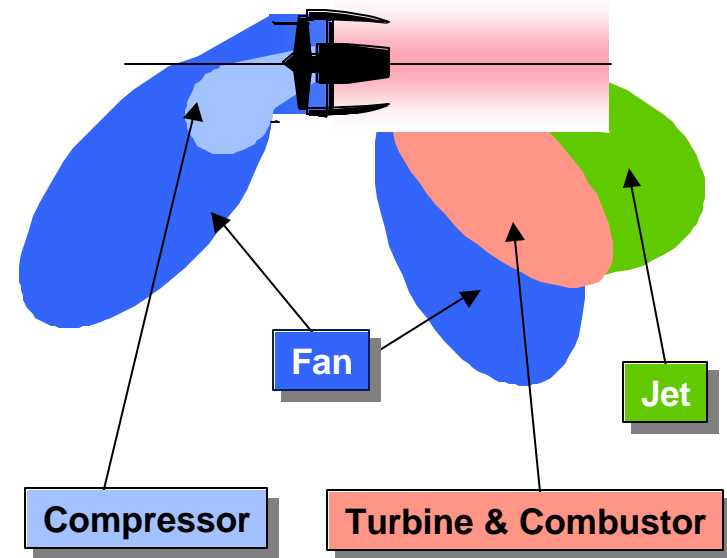
# Engine Noise Sources - Old versus New

*Noise of a typical 1960s engine*



Turbojets dominated by high jet exhaust noise at departure - loud roar, rumble

*Noise of a typical 1990s engine*



High-bypass-ratio turbofans dominated by fan noise - whine, whistle - and lower jet exhaust noise - roar, rumble



# Engine Noise Source Identification

## Fan:

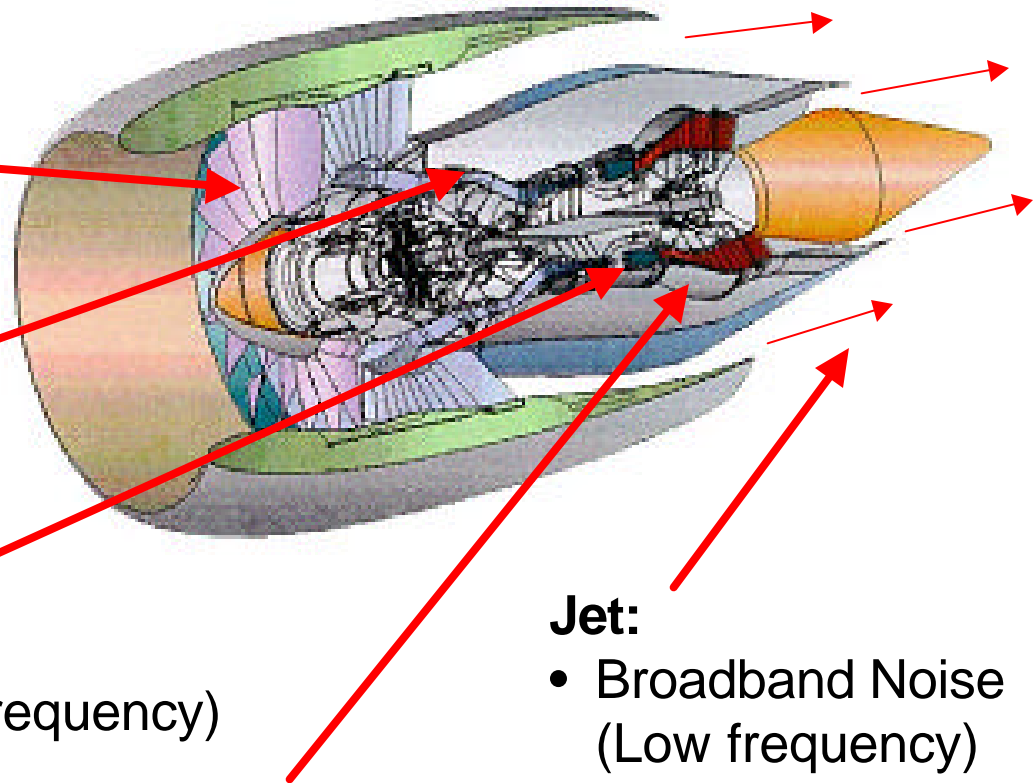
- Tones (All frequencies)
- Broadband Noise
- “Buzz-Saw” Noise

## Compressor:

- Tones (High frequency)
- Broadband Noise

## Combustor:

- Broadband Noise (Low frequency)



## Jet:

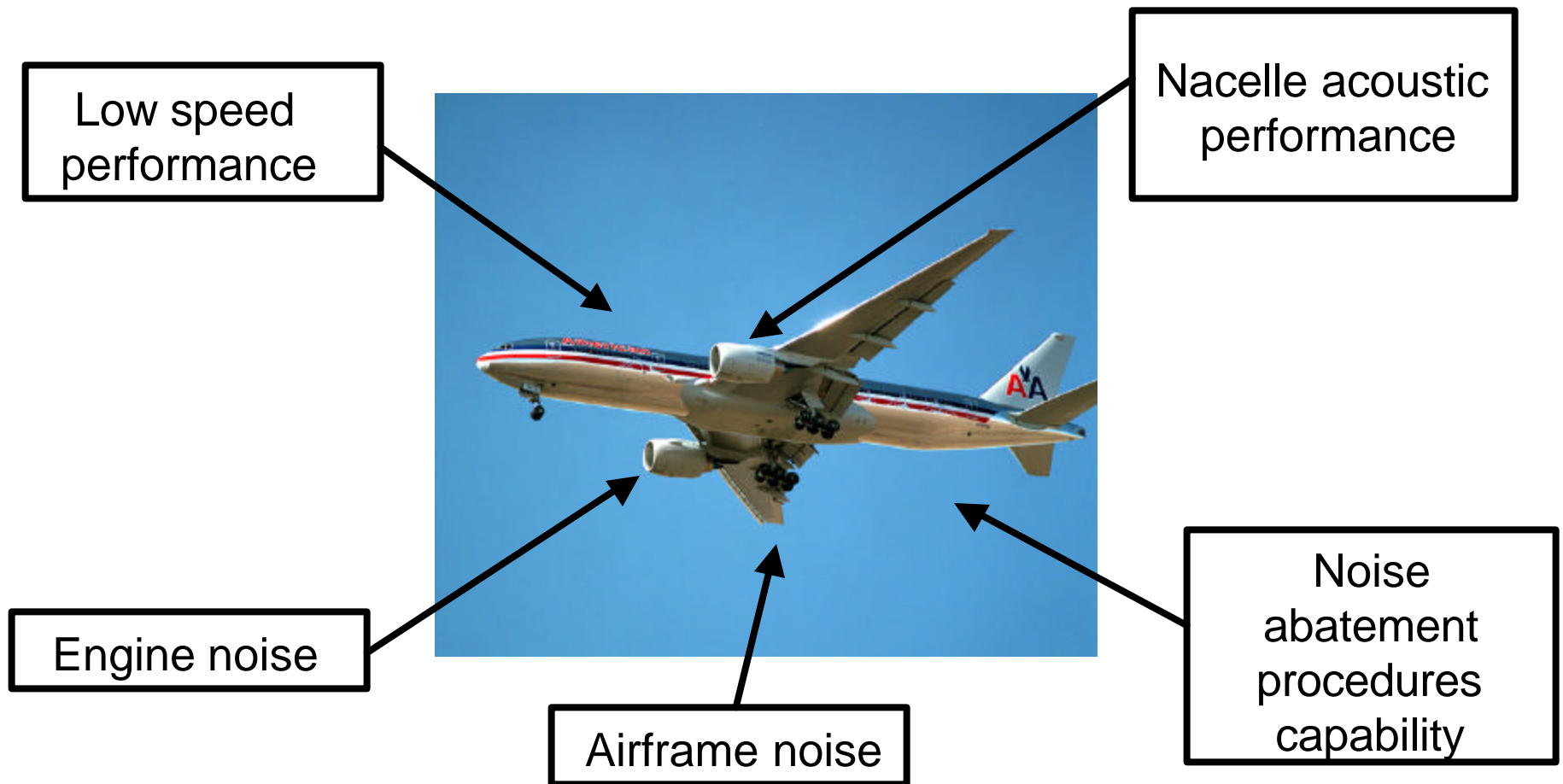
- Broadband Noise (Low frequency)

## Turbine:

- Tones (High frequency)
- Broadband Noise (High frequency)



# ***Noise is the result of the optimization of the aircraft as a global system***





## Noise Technology Development - Exhaust System Noise

### Very-high-bypass ratio

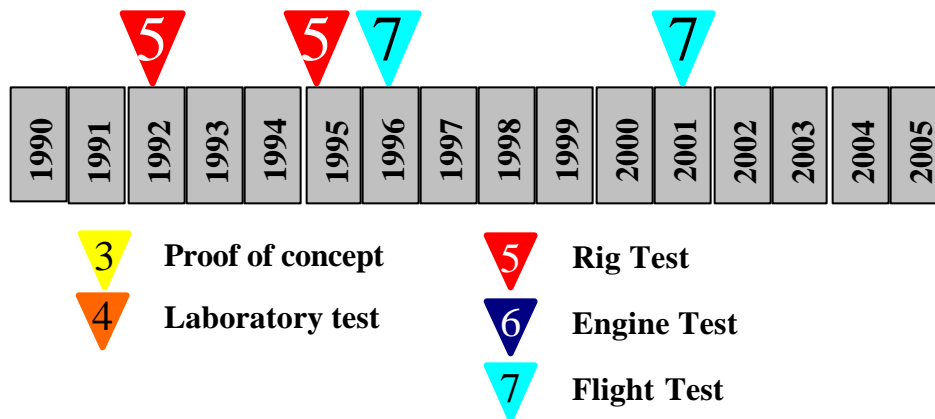


#### Approach:

- Reduce jet exhaust velocities
- Increase mass flow to achieve thrust

#### Potential noise reduction:

- Jet mixing noise - 3 to 5 dB



#### Key Issues:

- Increased installation drag and weight - engine is bigger in diameter
- Fan mechanical design  
- larger fan blades



## Noise Technology Development - Exhaust System Noise

### Nozzle Lip Treatment



#### Approach :

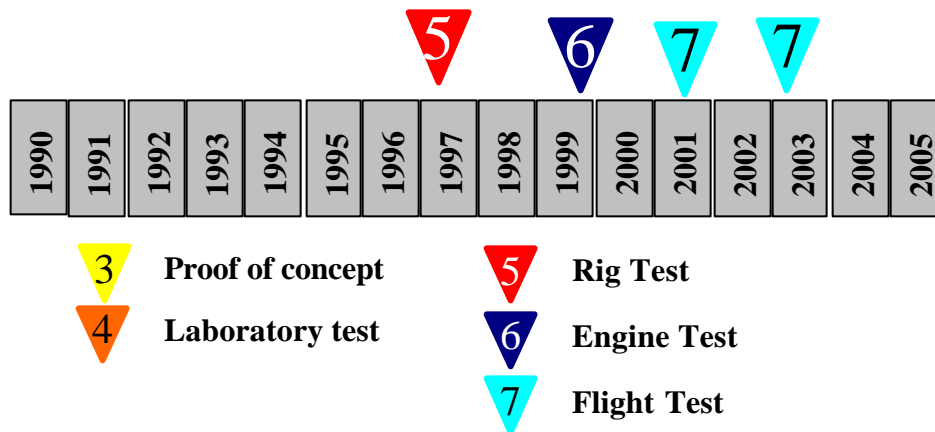
- Promote faster mixing of jet exhaust
- Minimize turbulence creation in mixing process

#### Potential noise reduction:

- Jet mixing noise - 2 to 4 dB

#### Key Issues:

- More effective at lower bypass ratios
- Aerodynamic losses - reduces thrust, increases fuel consumption
- Mechanical design - structural integrity, vibration



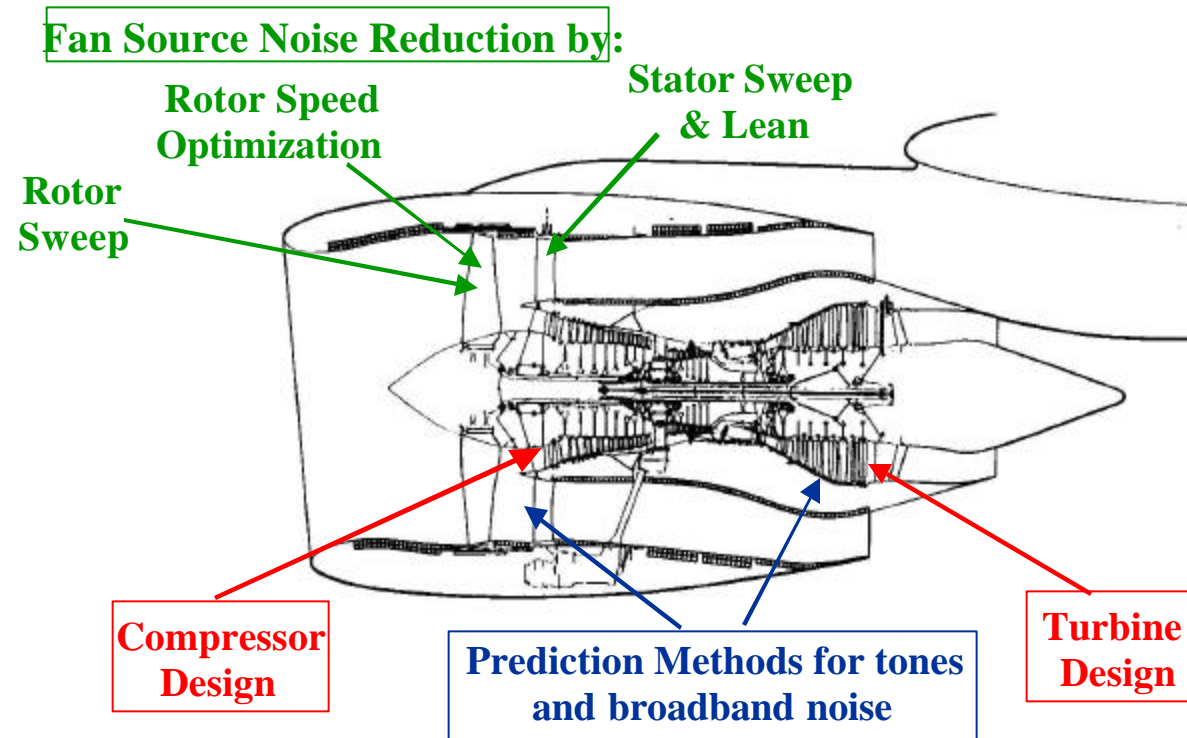


# Noise Technology Development Turbomachinery Noise

## ► *GOAL*

*Develop acoustic design concepts and optimization techniques for reducing source noise produced by fans, turbines and compressors of aircraft engines*

## ► *SCOPE*





## Noise Technology Development - Turbomachinery Noise

# Rotor Speed Optimisation



### Approach:

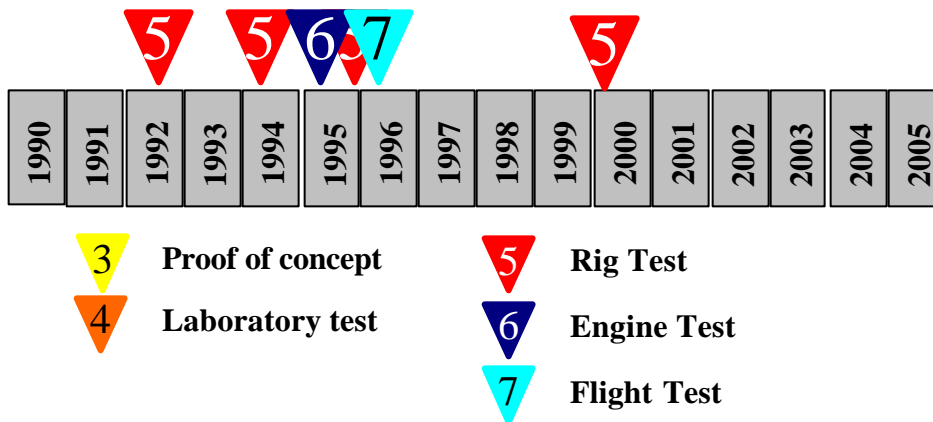
- Match fan tip speed to engine bypass ratio
- Reduce fan tip speed to minimise aerodynamic shocks ahead of fan rotor blades

### Potential noise reduction:

- Fan tone noise                      2 to 4 dB
- Fan broadband noise                1 to 3 dB

### Key Issues:

- Aerodynamic performance of fan, Compressor and LP turbine
- Geared Fan Penalty - Weight, Efficiency, Maintenance, Reliability, Cost
- Broadband noise (white noise) limits possible reductions





## Noise Technology Development - Turbomachinery Noise

### Rotor Sweep



#### Approach:

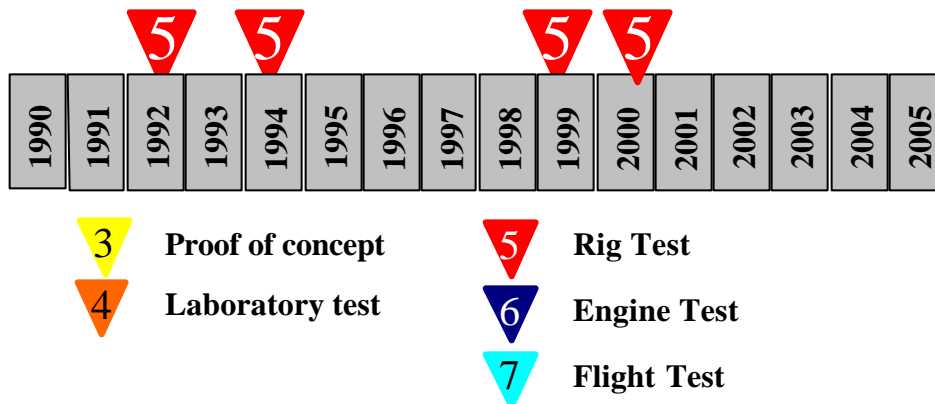
- Minimise aerodynamic shocks ahead of fan rotor blades

#### Potential noise reduction:

- Fan tone intake noise      2 to 4 dB (at take-off)
- Fan tone exhaust noise      1 to 3 dB

#### Key Issues:

- Fan aerodynamic and mechanical performance
- Fan blade stability and stall margin erosion
- Fidelity of Existing Prediction Models and Computer Codes





## Noise Technology Development - Turbomachinery Noise

# Stator Sweep and Lean



### Approach:

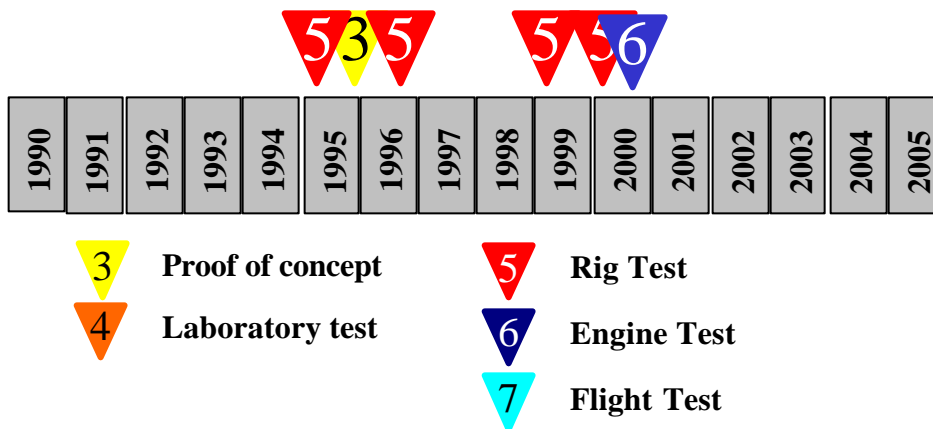
- Reduce unsteady loading on stators
- Reduce efficiency of radiation of stator noise

### Potential noise reduction:

- Fan tone intake noise      2 to 4 dB (at approach)
- Fan tone exhaust noise      3 to 5 dB
- Fan broadband noise      2 to 3 dB

### Key Issues:

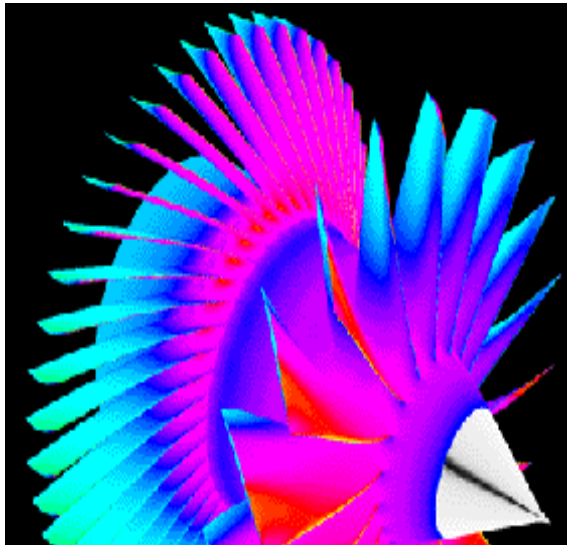
- Manufacturing Complexity
- Manufacturing Cost
- Fan Aerodynamic Performance Impact





## Noise Technology Development - Turbomachinery Noise

# Improved Prediction Methods



### Approach:

- Develop advanced computational models for predicting aerodynamics and noise of fan system

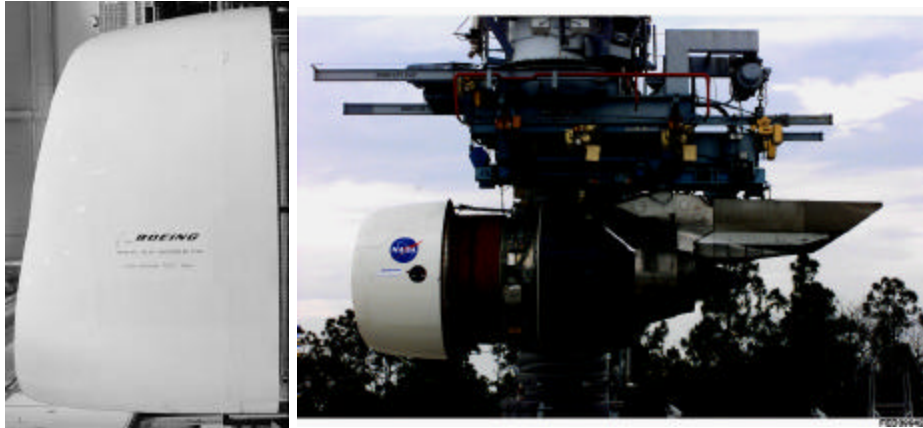
### Key Issues:

- Correct Modelling of Physics
- Computational Accuracy
- Numerical Algorithm Efficiency
- Computer Code Validation



# Noise Technology Development – Nacelle Acoustics

## Negative Scarf Inlet



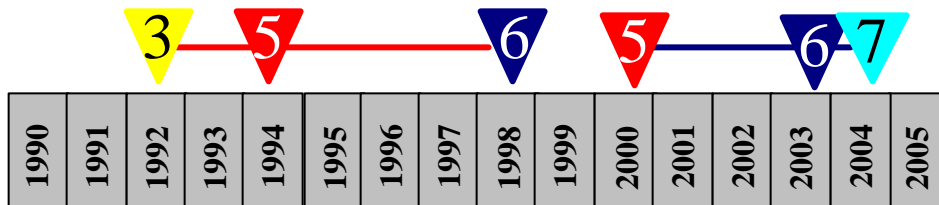
Prototype Engine Test

### Approach:

- Redirection of sound away from ground

### Potential noise reduction:

- Forward fan noise 2 to 4 dB



3 Proof of concept  
4 Laboratory test

5 Rig Test  
6 Engine Test  
7 Flight Test

### Key Issues:

- Aerodynamic Performance Penalty
- Weight penalty
- Non retrofittable
- Potential Fan Blade Redesign
- Potential cabin noise increase



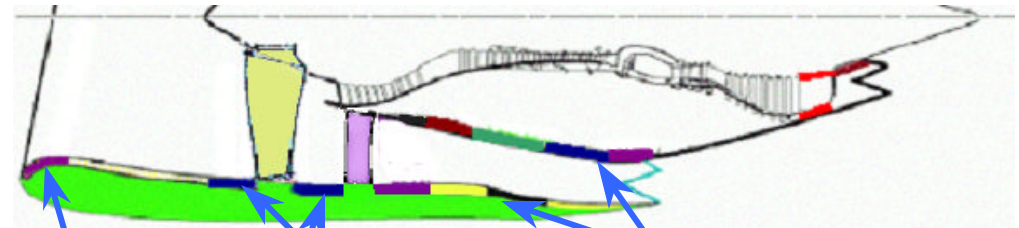
# Noise Technology Development – Nacelle Acoustics

## Maximize Acoustic Area



### Approach:

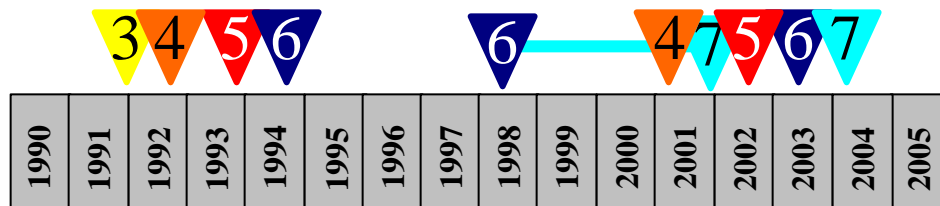
- Extend acoustic liner areas
- Minimize splices and gaps



Lip Liner

Case liner

By-pass duct liners



3 Proof of concept  
4 Laboratory test

5 Rig Test  
6 Engine Test  
7 Flight Test

### **Potential noise reduction:**

- Fan noise 2 to 5 dB

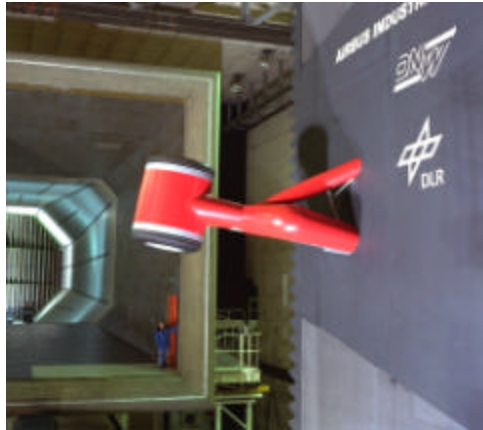
### **Key Issues:**

- Advanced Anti-icing System
- Aero performance penalty
- Structure integrity
- Weight, cost, and Maintenance



# Noise Technology Development – Airframe Acoustics

## Landing Gear Fairing and Low Noise Design



Landing Gear with fairing in wind tunnel

### Approach

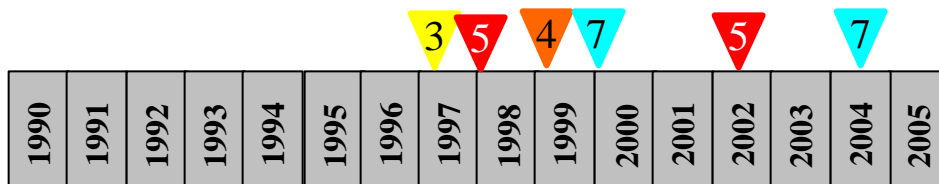
- Minimise flow separations around landing gear to reduce noise

### Potential noise reduction:

- Improved Landing Gear design: 1 dB
- Noise Reduction Treatments: 3- 4 dB

### Key Issues:

- Fairing designs which allow easy access for maintenance
- Weight
- Ability to stow gear



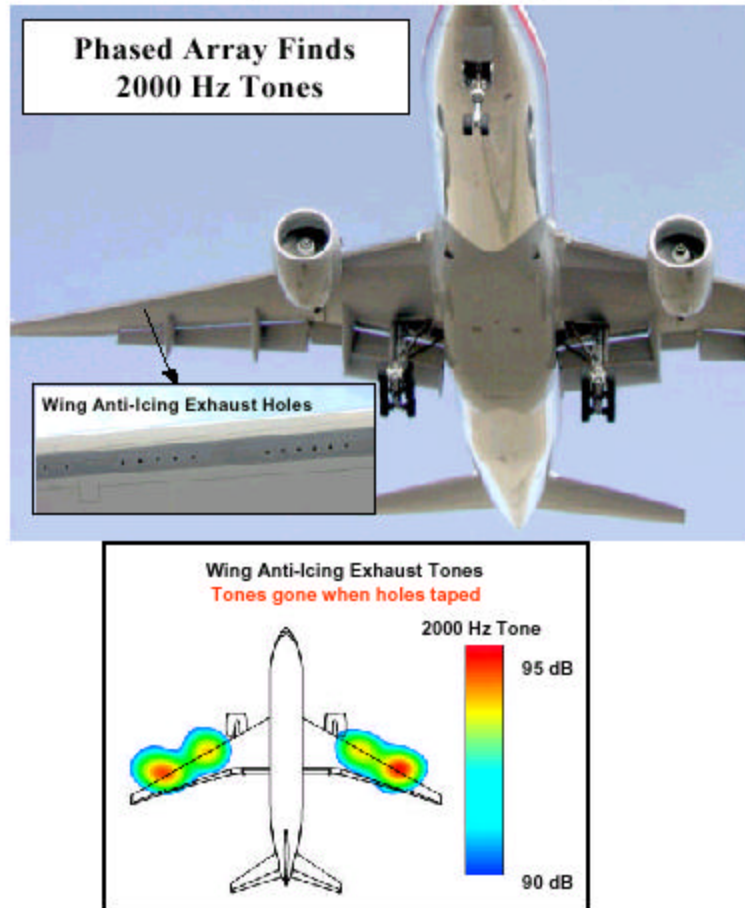
3 Proof of concept  
4 Laboratory test

5 Rig Test  
6 Engine Test  
7 Flight Test



# Noise Technology Development – Airframe Acoustics

## Fly-over noise mapping with acoustic antenna



### **Approach:**

- Fly-over noise map with phase-array “acoustic camera” to identify noise sources

### **Potential noise reduction:**

- Can identify noise sources reduction
- Can distinguish between engine and airframe sources

### **Key Issues:**

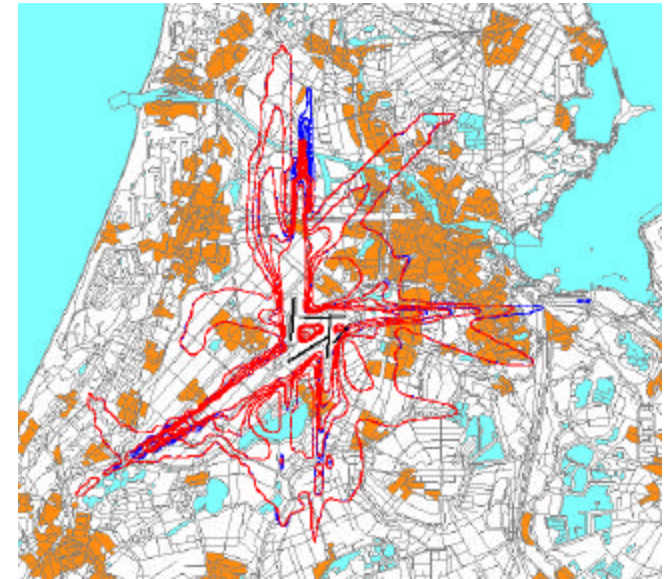
- Technology available today



## Noise Technology Development Noise Abatement Procedures (NAP)

### ▶ **GOALS**

*Define new noise abatement procedures, evaluate environmental, economical and operational impacts, specify Flight Management and Air Traffic Control (ATC) Systems change requirements, validate new procedures*

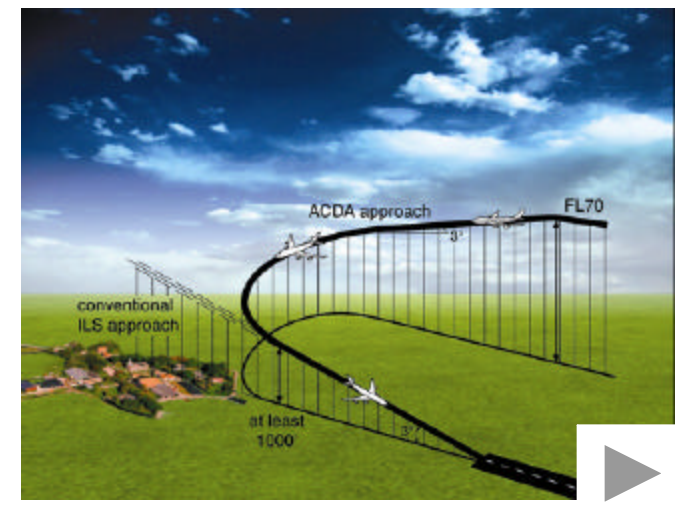


### ▶ **SCOPE**

*Departure & Arrival procedures*

*Step1: existing aircraft, using existing ATC infrastructure.*

*Step2: may require additional certification, development of aircraft avionics and ATC tools or equipment*





# SUMMARY

- There have been major improvements in aircraft noise over the last 40 years
- The aircraft, engine and nacelle manufacturers in the U.S. and Europe along with their governments and research organizations continue to aggressively pursue aircraft noise reduction
- Technological advances are required in all aspects of aircraft, engine and nacelle design if there is to be significant improvement in aircraft noise
- Research funding will be crucial to achieve the significant noise reductions we have seen in the past