ELEMENTARY SOURCE ARRAYS IN THE SYNTHESIS OF ACOUSTIC FIELDS DUE TO TURBULENT FLUCTUATIONS AROUND FUSELAGE PANELS

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Summary

- **Introduction and Motivation**
- **The Cabin Acoustic Problem**
- **General method**
- **Monopole Source Synthesis Optimization**
- **Some Results**
- **Main Conclusions**

Motivation

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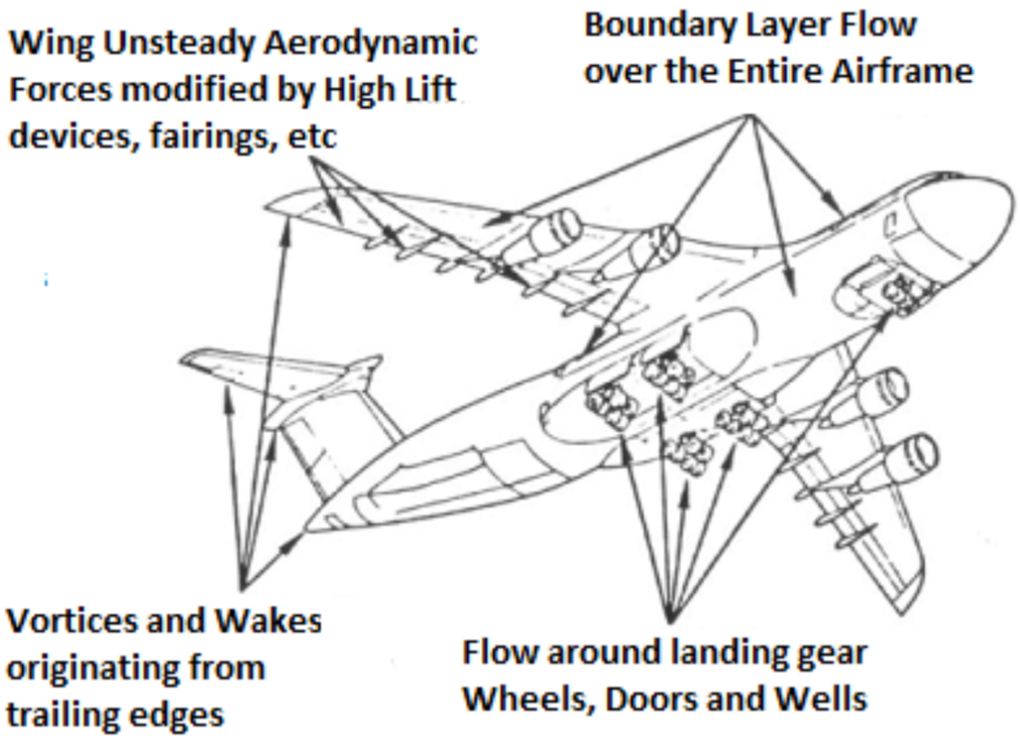
Together with the more demanding quieter cabins:

- **New construction techniques and technology have modified the environment inside an aircraft**
- **Cost effective and more flexible evaluations are needed.**

Aircraft Noise Sources



OUTSIDE NOISE SOURCES

plus
INTERNAL NOISE SOURCES (ECS etc)

Cabin Comfort

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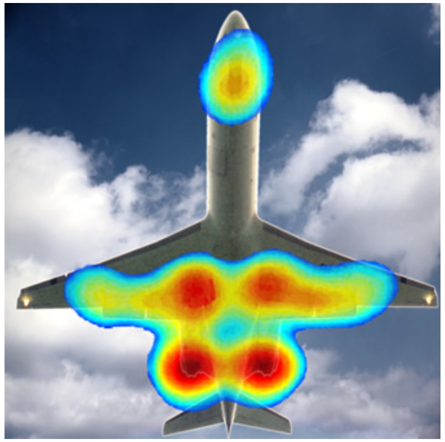
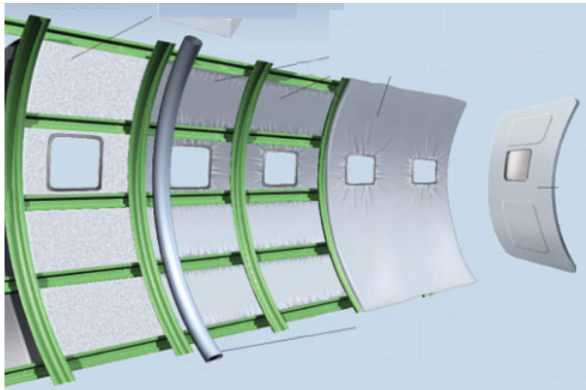




SOURCE X **PATH** = **RECEIVER**

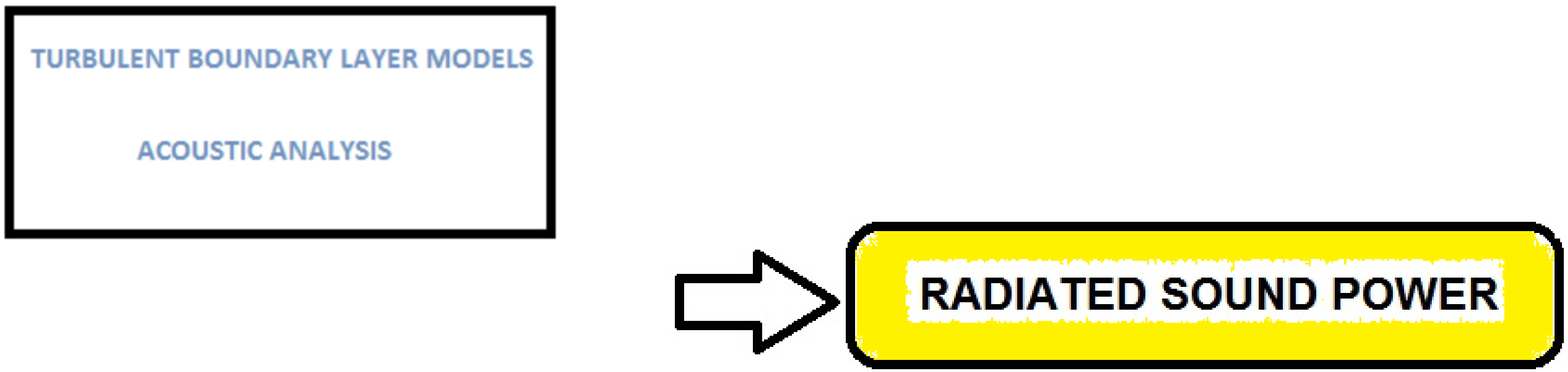
- **Engine Flow**
- Engine Vibration
- Engine Combustion
- **Body Boundary Layer**
- **High Lift Devices**
- **Undercarriage**
- E C S

- Structural path
- Vibro-acoustic path

- Internal Noise
- Vibration
(stronger in piston engine)

Boundary Layer Noise

- **Global Two Dimensional Turbulent Boundary Layer Models**
- **The problem to be looked at cruising regime!**



Obtaining TBL models

- OBJECTIVE: To obtain → Total Energy
- A VARIETY OF METHODS: going back to the 1960s
- INPUTS: Flight regimes (Re, Ma, etc)
- ALSO: Vortex Shedding (Sh,etc)

Results: TBL models

- **STATISTICS: Statistics → Mean Square Pressure+(Single) Wall Pressure Spectrum + Normalized Wave Number Spectrum. (the need to obtain total energy and spectrum distribution)**
- **MODELING: Analytic/Empiric + Numeric Methods (LES/DES models, etc)**
- **QUALITY OF MODELS: Strong dependence on flight conditions**
- **RESULTS: → Power Spectral Density (PSD) outputs**

The Point: New Demands

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- **Increased use of composite materials, with different damping properties, and also:**
- **Substantial modification in panel stiffness**
- **Change in construction techniques have also modified “interference” damping!**
- **Transmission and Radiation changes require improved corrections**

Evaluation Strategy

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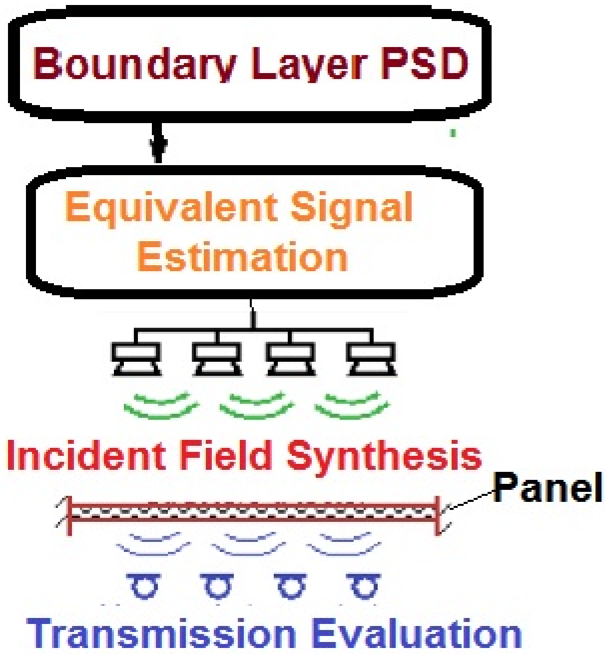
- **Flight or Wind Tunnel Testing are expensive**
- **Source control can be a problem**
- **Therefore: The introduction of an equivalent source array!**



Implementing simulated TBL

- ✓ **Aerodynamic improvements (particularly for high lift devices) is a key issue but that is another research(*)**
- ✓ **Present models for Turbulent Boundary Layer (TBL) noise are quite reasonable**
- ✓ **Monopole source modeling(*) is efficient and easier to achieve**

Monopole modeling

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Monopole Complex Free Field Sound Pressure

$$p(r,k) = -j\omega\rho_0 Q \frac{e^{jkr}}{4\pi r}$$

And the Superposition using the Image Method

$$p(r^-,k) + p(r^+,k) = -j\omega\rho_0 Q\left(\frac{e^{jkr^-}}{4\pi r^-} + \frac{e^{jkr^+}}{4\pi r^+}\right)$$

Resultant Pressure for an array having n monopoles

$$p(x_j, y_j, z_j, k) = -j\omega\rho_0 \sum_{i=1}^{n} Q_i \left[\frac{e^{jkr_{ij}^-}}{4\pi r_{ij}^-} + \frac{e^{jkr_{ij}^+}}{4\pi r_{ij}^+}\right]$$

General Propagation Model having m measurement points over a panel

$\mathbf{Aq} = \mathbf{p}$ (Transfer Matrix **A**)

Acoustic Synthesis

Acoustic Synthesis (inverse Optimized Problem)

$$\min \left\| \mathbf{Aq} - \mathbf{p} \right\|_2$$

Truncaded Singular Value Decomposition to achieve Matrix Conditioning

$$\mathbf{q}_{TSVD} = \sum_{i=1}^{k} \sigma_i^{-1} (\mathbf{u}_i^H \mathbf{p}) \mathbf{v}_i = \left(\mathbf{A}_k^H \mathbf{A}_k \right)^{-1} \mathbf{A}_k^H \mathbf{p}$$

Sound Power Model

Particle Velocity obtained from superposition and Sound Power Model

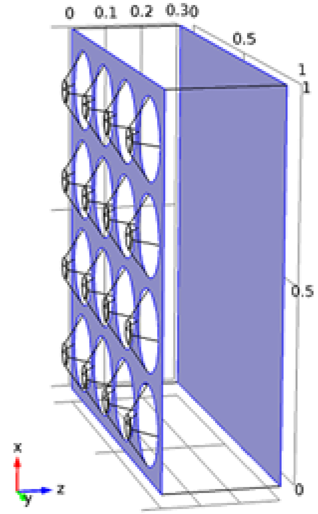
$$\mathbf{B}\mathbf{q} = \mathbf{u} \quad \text{(Velocity Transfer mxn Matrix } \mathbf{B}\text{)}$$

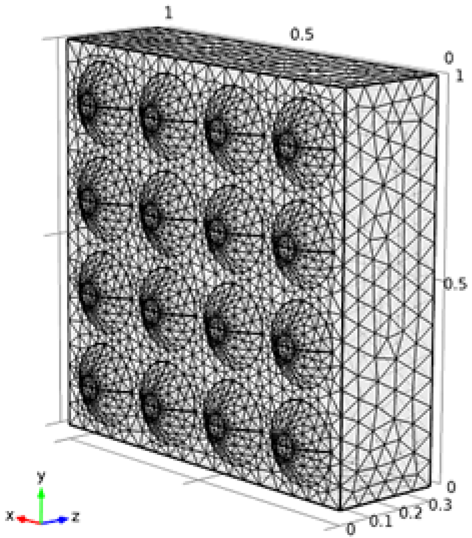
Sound Power Model over a surface S

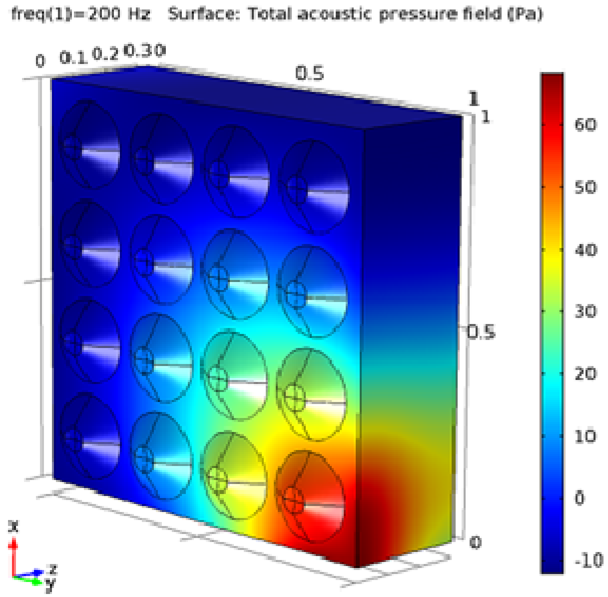
$$\Pi \approx \frac{\Delta s}{2} \mathbf{q}^H \mathbf{B}^H \mathbf{A} \mathbf{q}$$

$$\mathbf{W} = \mathbf{B}^H \mathbf{A}$$

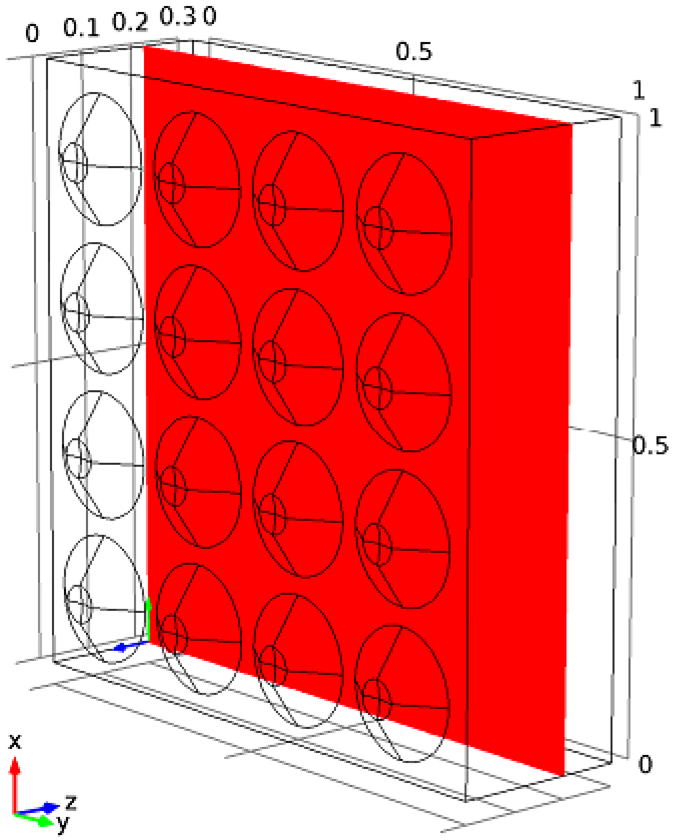
Equivalent Source Array

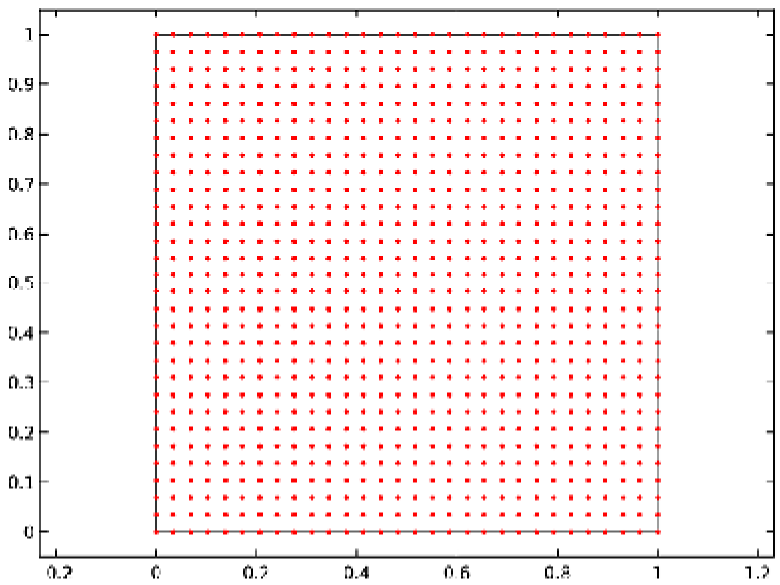






Panel Excitation





PROBLEMS?

- **Acoustic Chamber requirements to provide free field conditions (*)**
- **Electric power and transducer requirements can be problem, requiring scaling (**)**

Main Conclusions

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- New construction Technologies require renewed assessment of aircraft cabin noise evaluation which can be made easier with:
- (Simulated) Monopole Acoustic Source Synthesis, minimizing Wind Tunnel and Flight Testing
- However for actual testing both electric power and transducer requirements have to be carefully considered
- The research continues......

Thank you very much

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