

# Fuselage Excitation During Cruise Flight Conditions: From Flight Test to Numerical Prediction

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Knowledge for Tomorrow

# Overview

- Introduction
- Flight test data overview
- Literature TBL prediction models
- CFD calculation and analysis
- New CFD and CAA based TBL prediction models
- Coupling TBL models with SEA
- Results & Outlook



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# Overview

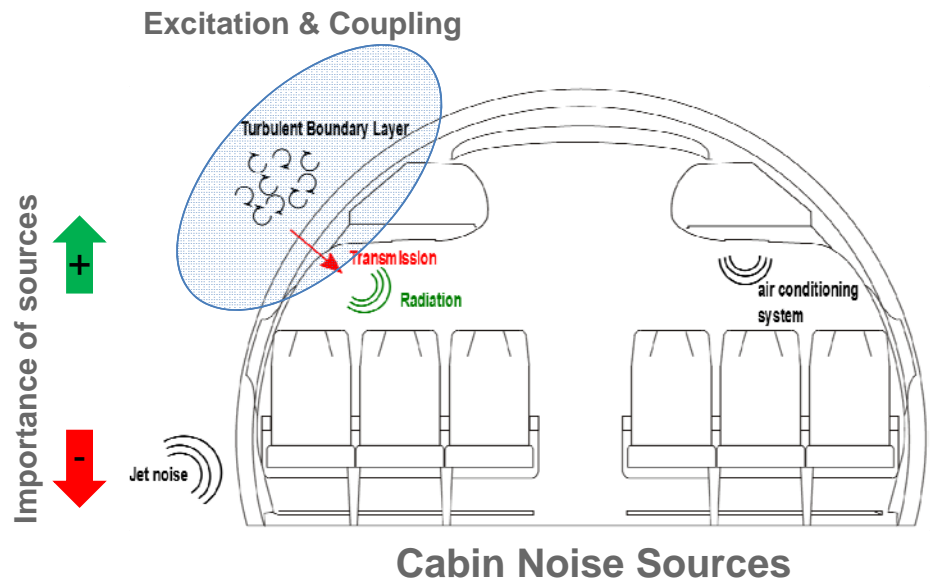
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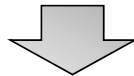
# Introduction



**\*Turbulent Boundary Layer**



# Introduction

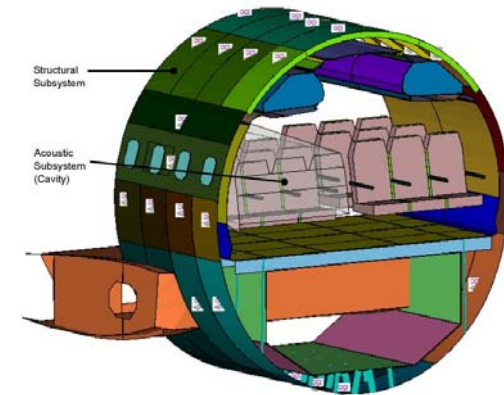
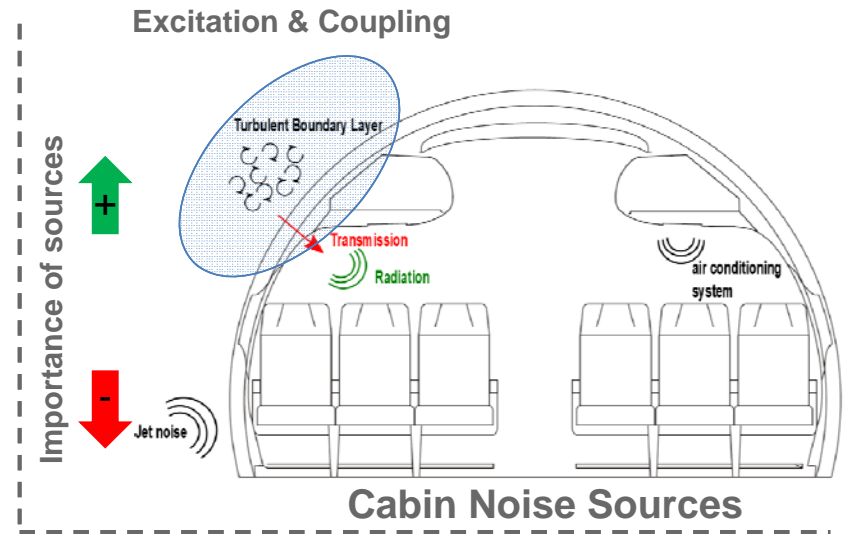
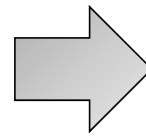


Development of models for **EXCITATION**:

1. Auto-spectra prediction
2. Wavenumber-freq. spectra prediction

based on flight test data and numerical methods (CFD & CAA), and

3. Investigation of **COUPLING** methods
4. Calculation of structural vibration



Statistic Energy Analysis



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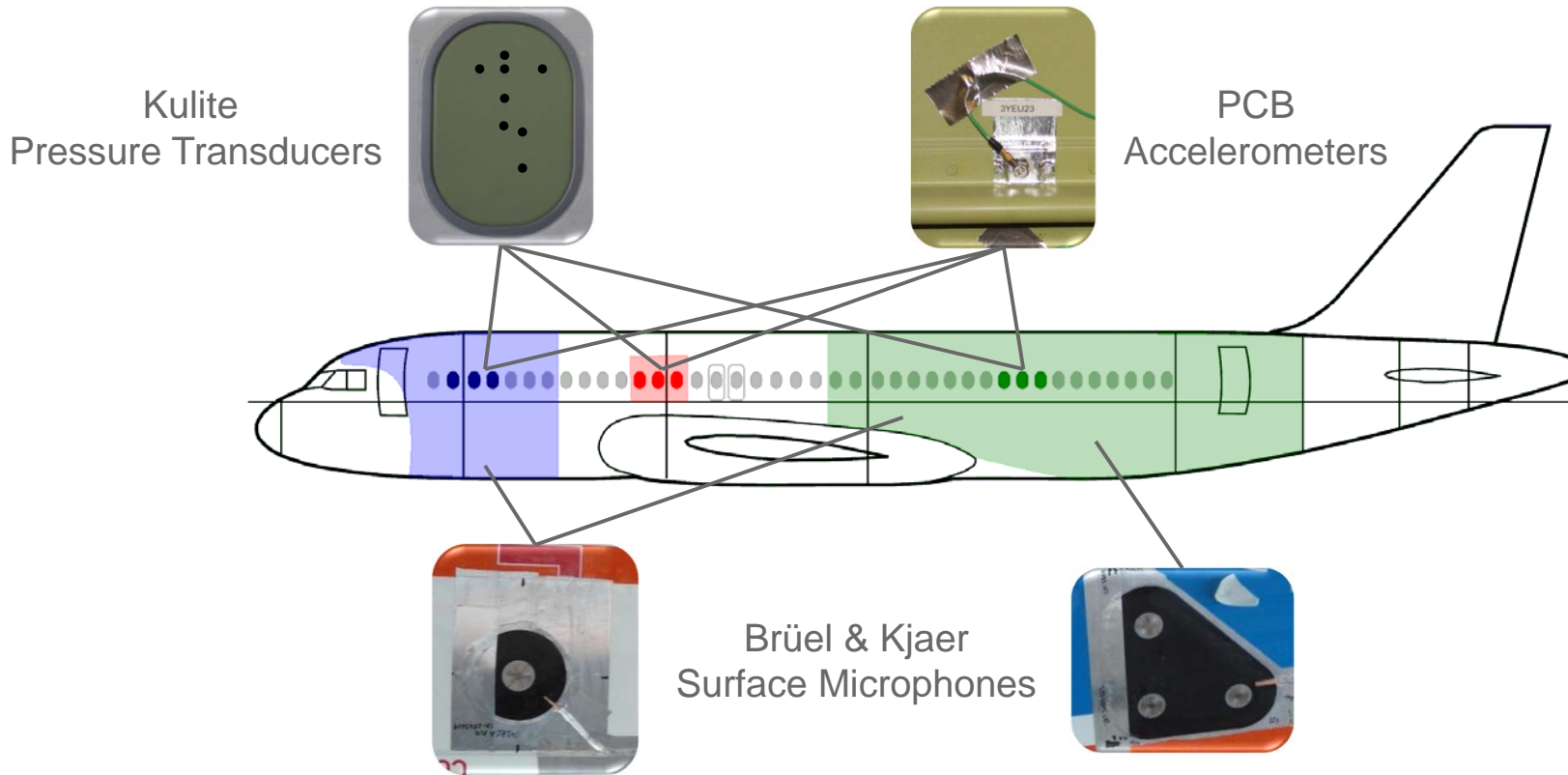


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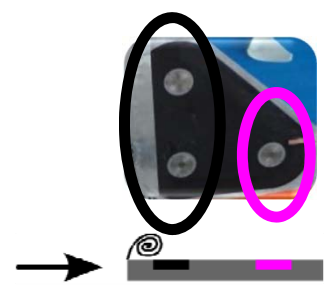
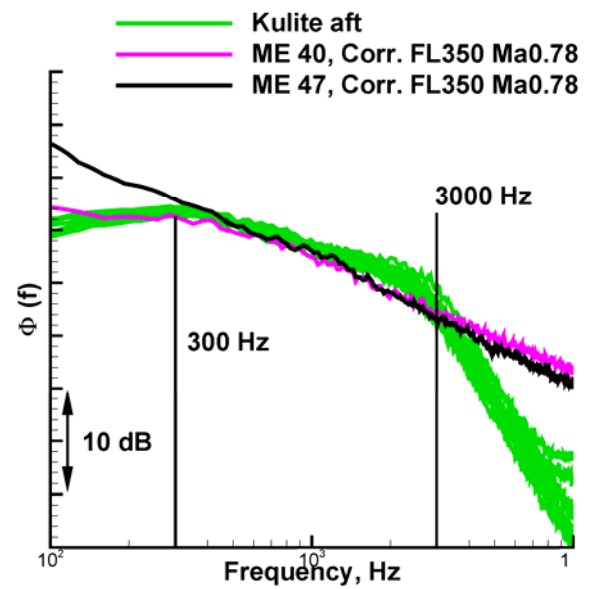
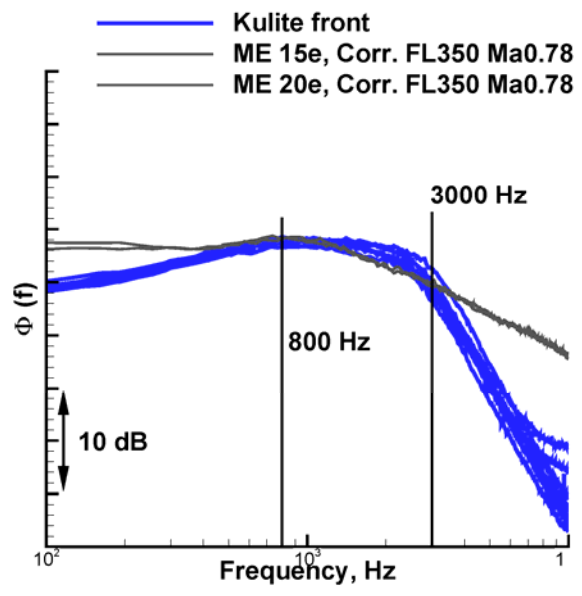
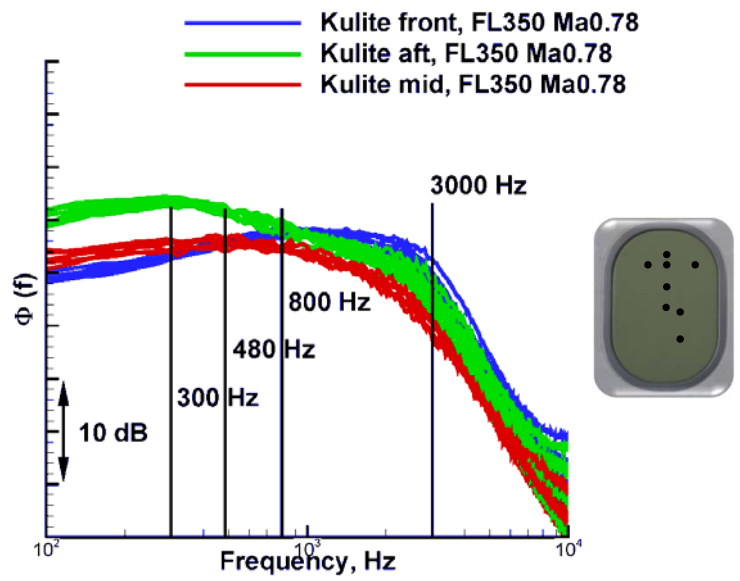
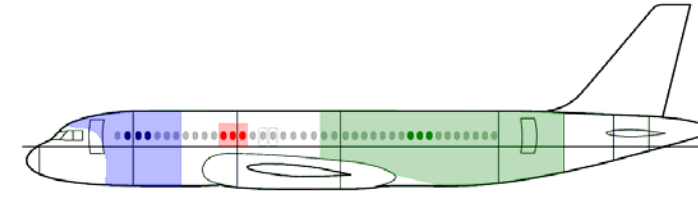


# Flight test data overview

## Sensors

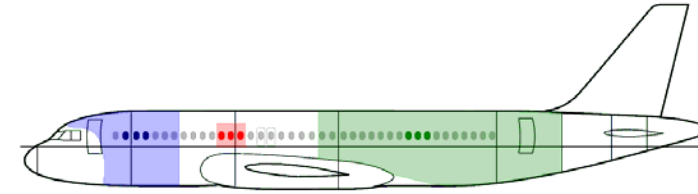


# Flight test data overview Analysis

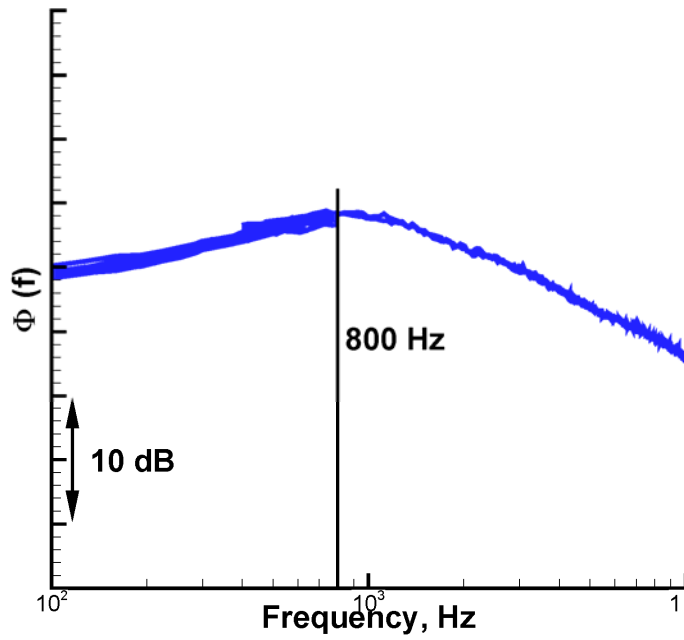


# Flight test data overview

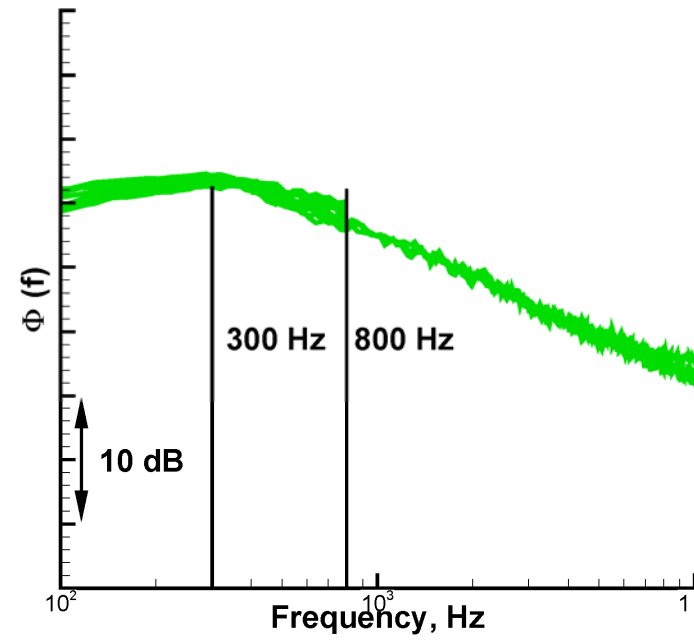
## Validation Auto-Spectra



Validation Spectrum Front



Validation Spectrum Aft



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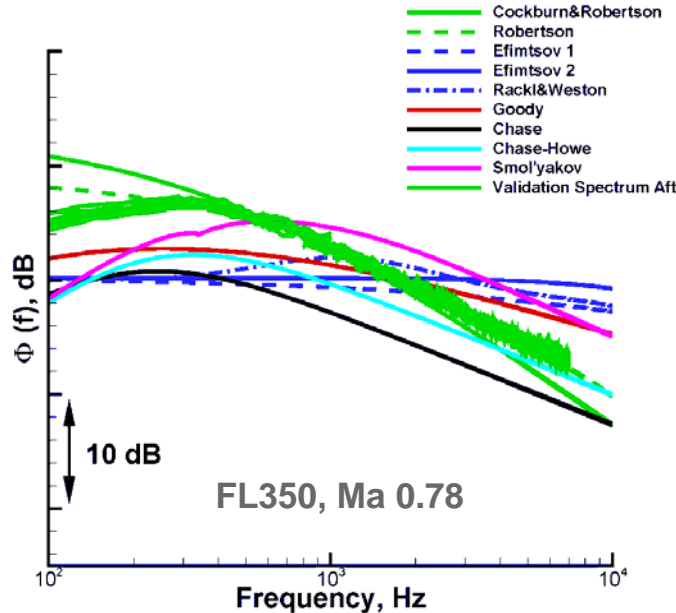
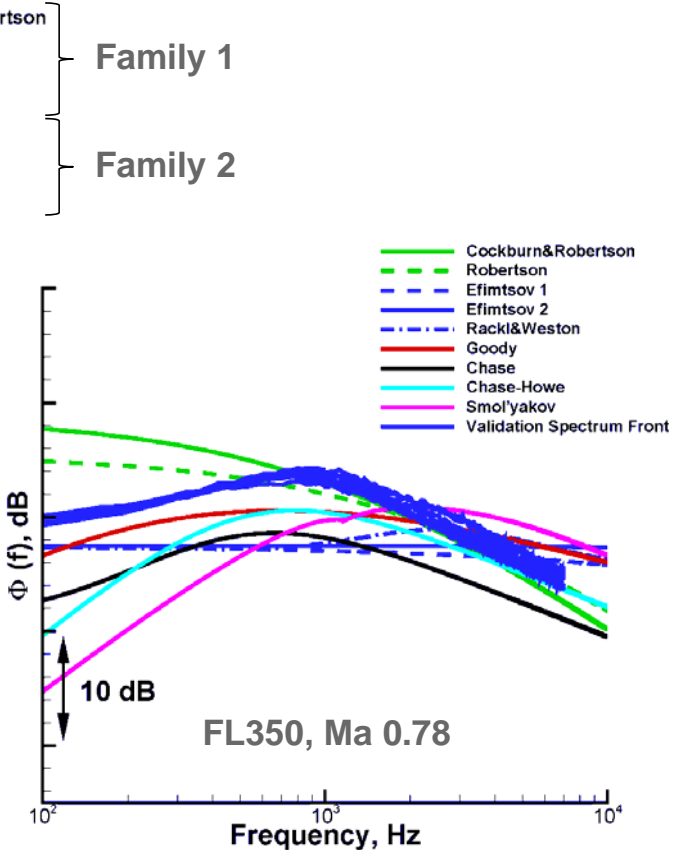
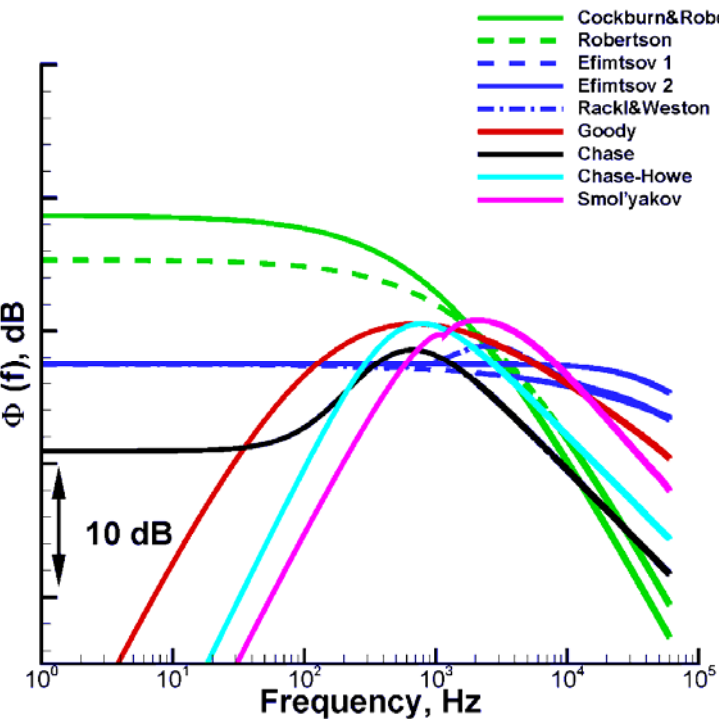
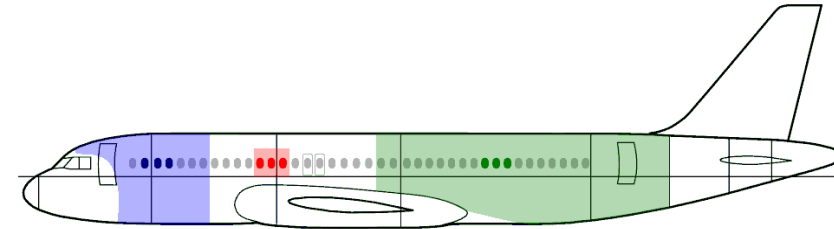


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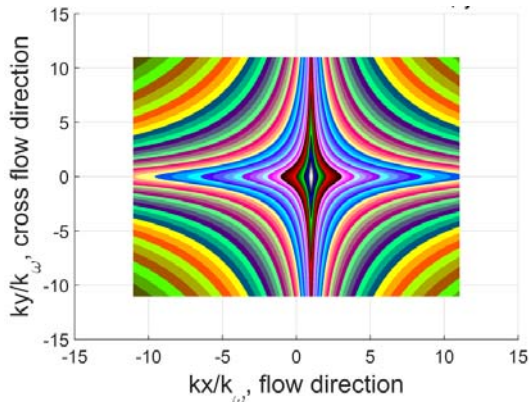
# Literature TBL prediction models

## Auto-Spectra

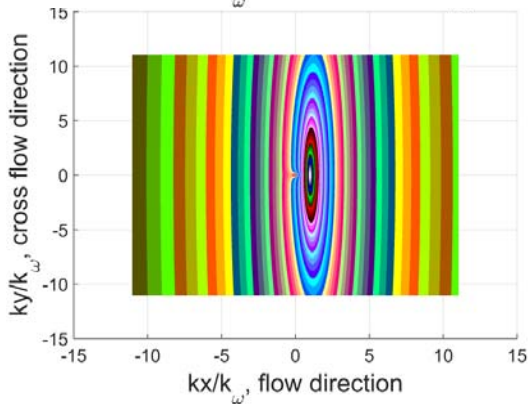
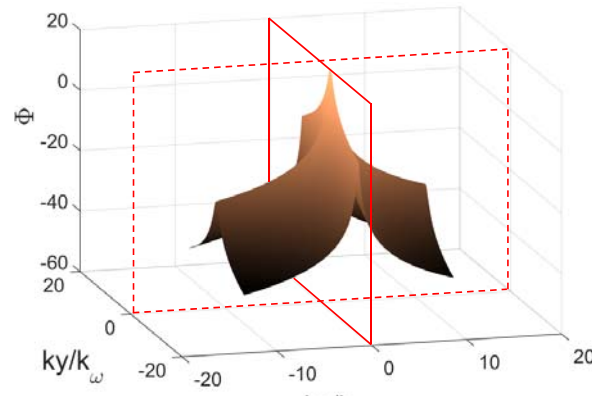


# Literature TBL prediction models

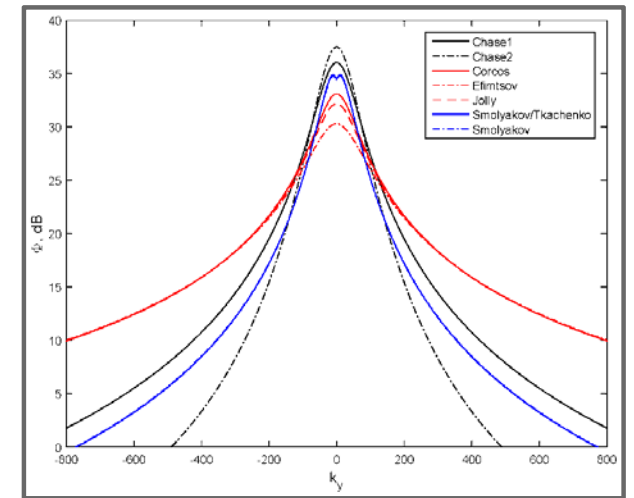
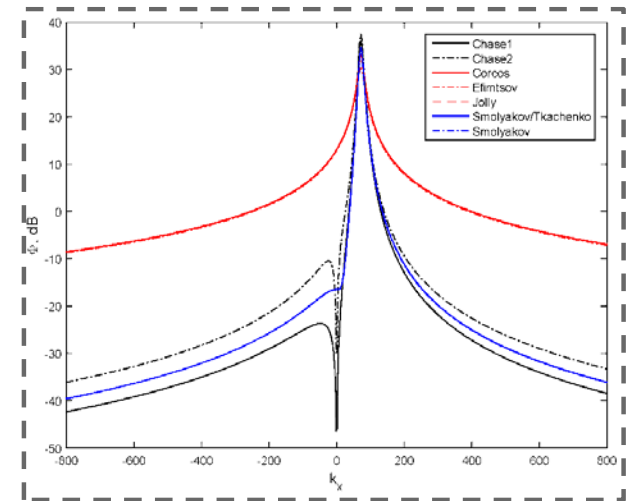
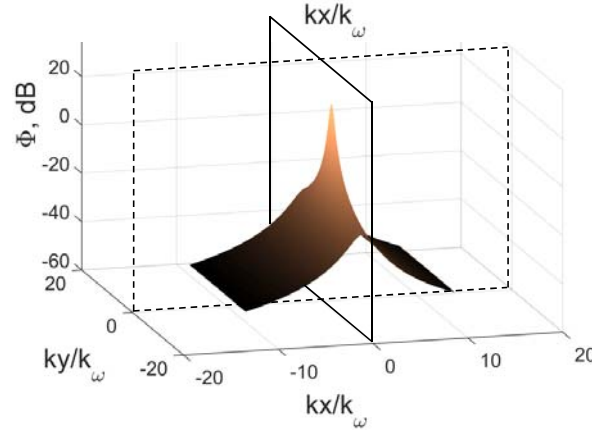
## Wavenumber-Frequency Spectra



Rhombic Models  
(Corcos)



Elliptical Models  
(Chase)



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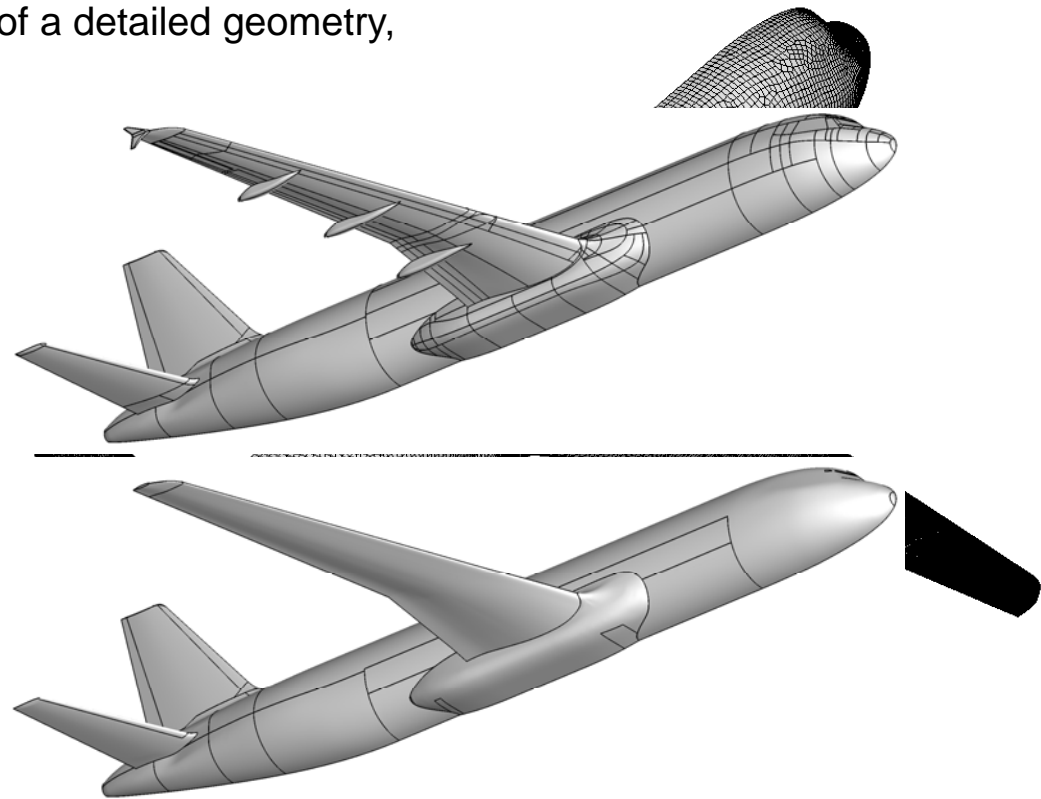
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## CFD calculation and analysis

RANS (TAU) simulation with RSMg turbulence model of a detailed geometry, including HTP, VTP and clean wings

Flight level	TAS [m/s]	AoA [°]
310	234	1
	245	0.9
350	237	2
	247	2, 3, 4
390	234	2.7
	245	2.7

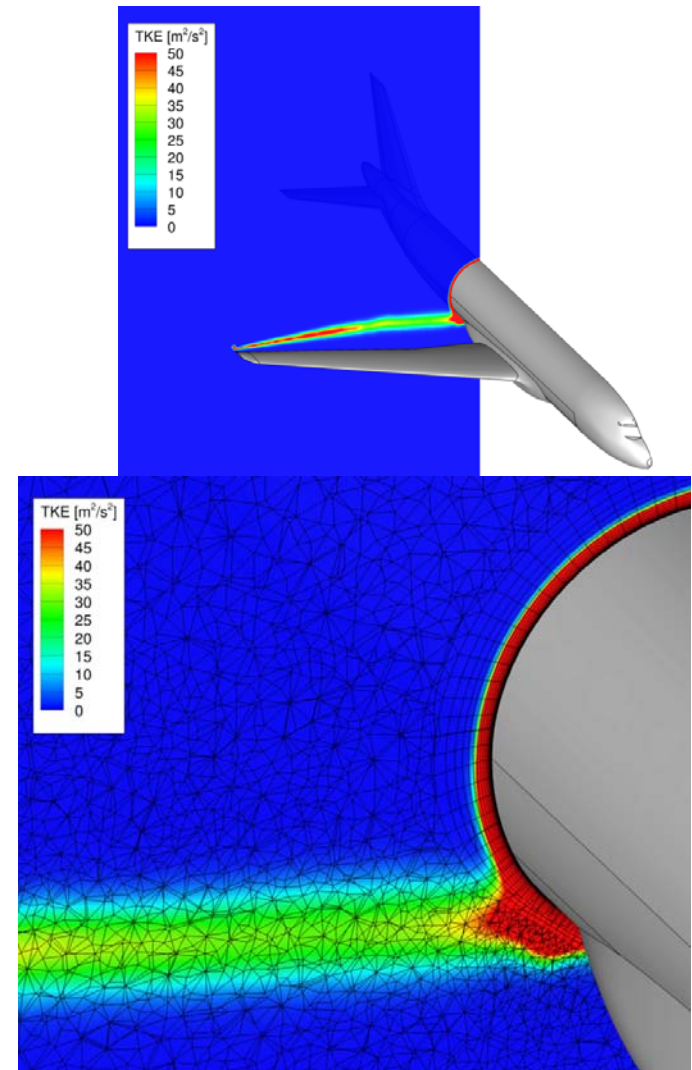


- Stretching factor 1.2



## CFD calculation and analysis

- Focus is on the analysis of:
  - Pressure coefficient
  - Local boundary layer thickness
  - Local edge velocities
  - Local flow directions
  - Turbulence kinetic energy
  - And further parameters, which are important for the auto-spectra models
- Boundary layer thickness as well as the local flow direction is validated by in-flight measured data



# Overview

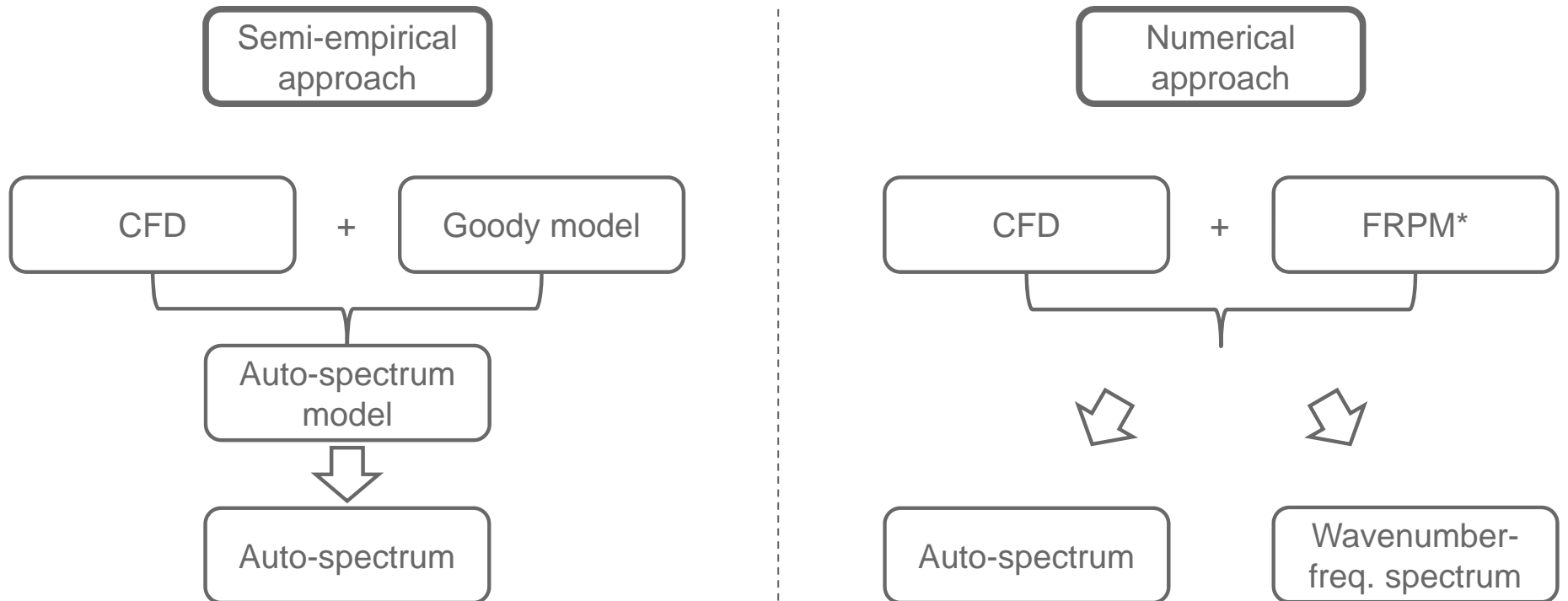
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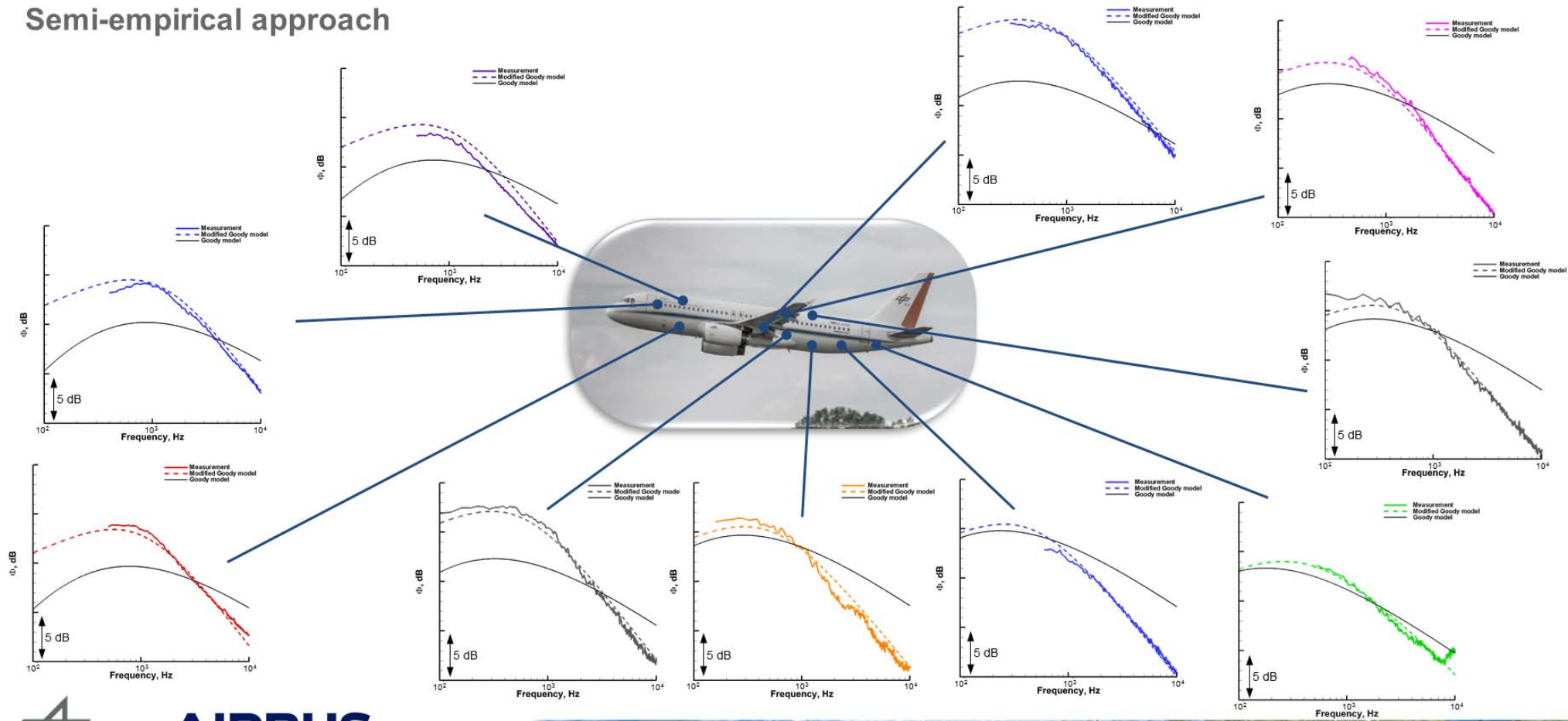


## New CFD and CAA based TBL prediction models



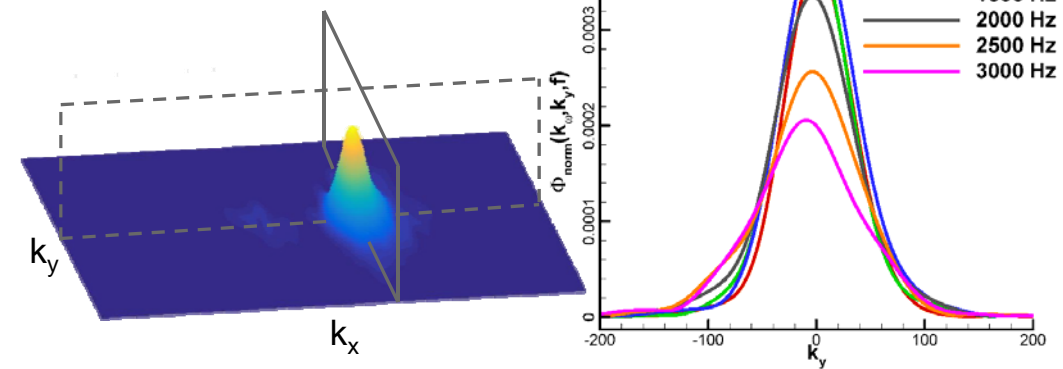
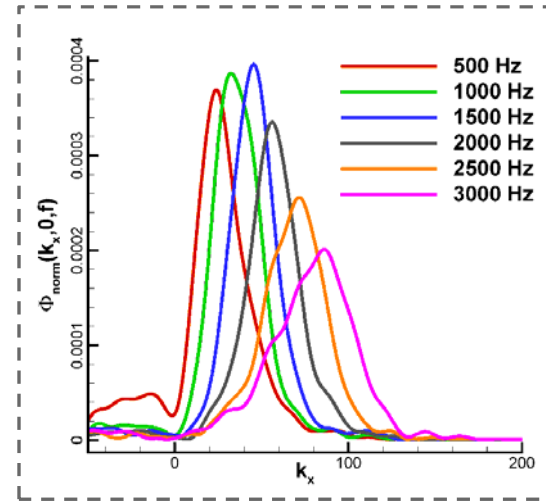
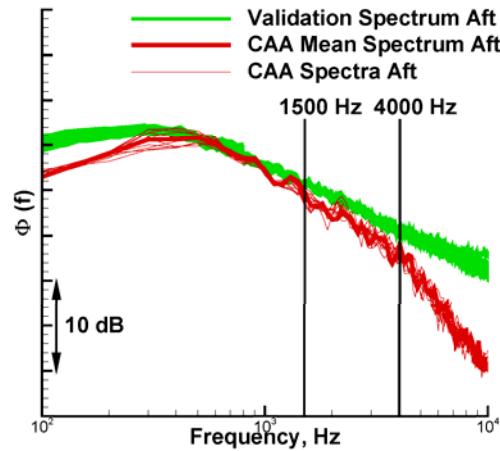
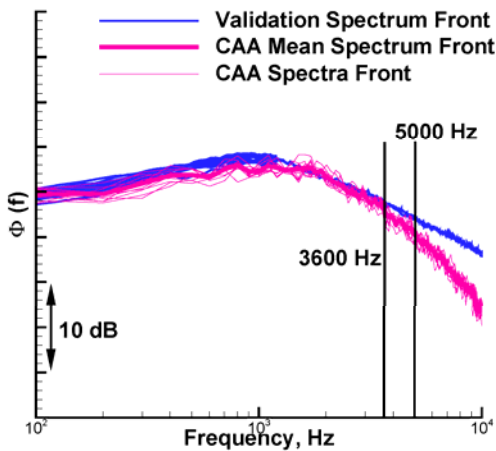
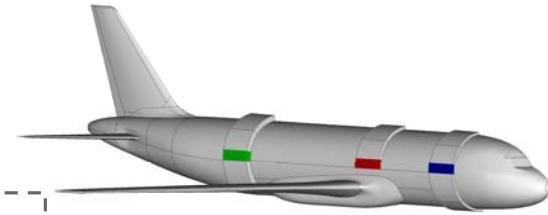
# New CFD and CAA based TBL prediction models

## Semi-empirical approach



# New CFD and CAA based TBL prediction models

## Numerical approach



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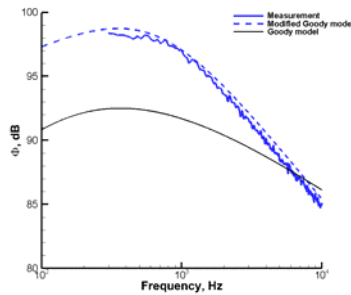
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# Coupling TBL models with SEA

**Auto-spectra**

Sorts the energy of turbulence into frequencies



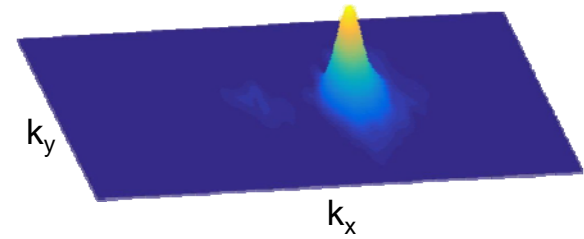
**Grahams method**      **VA 1**

Calculates the coupling of TBL & fuselage structure  
→ Structural vibration



**Wavenumber-freq. spectra**

Information about space & time development of turbulence



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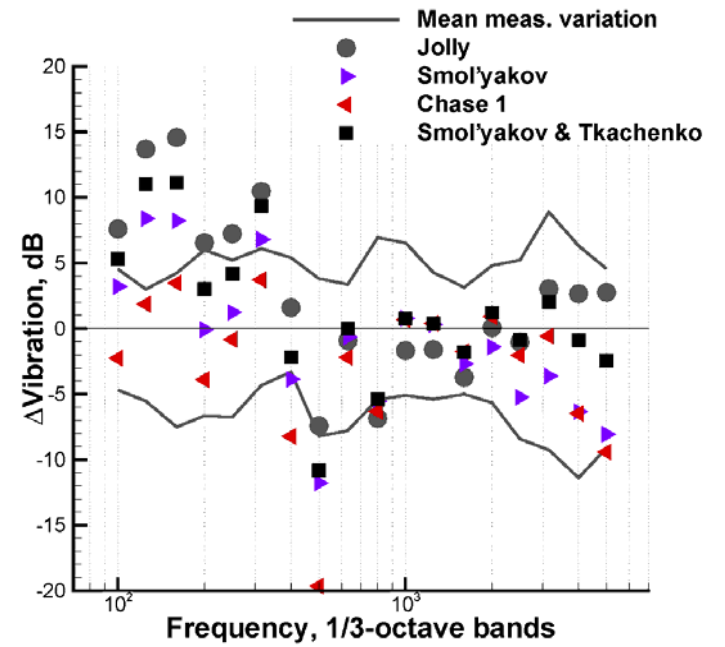
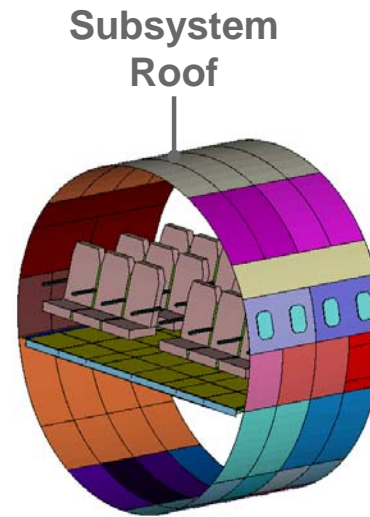
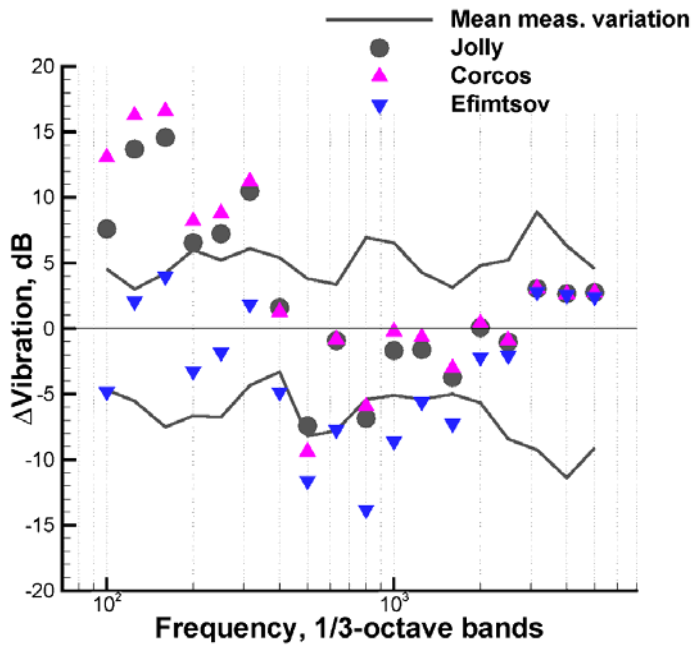
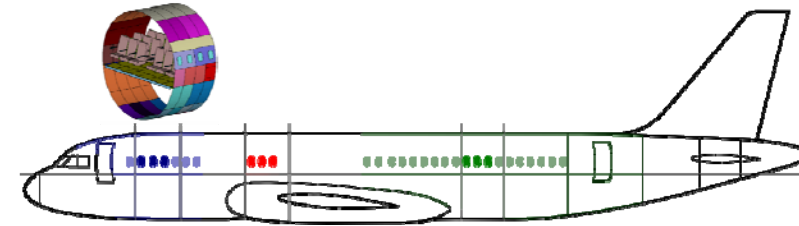


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# Results & Outlook

## A320

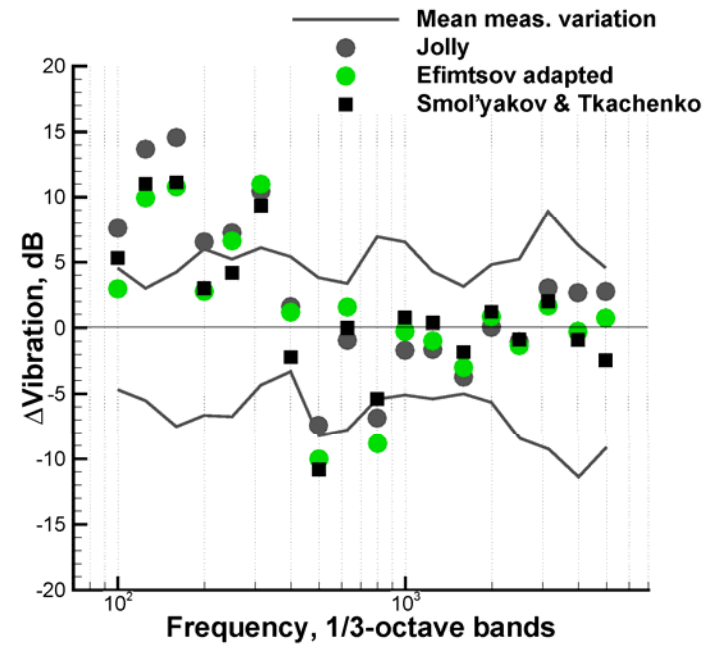
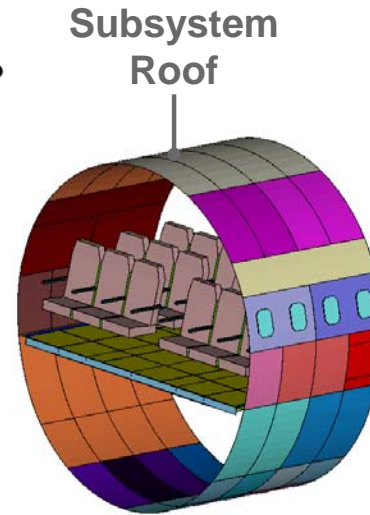
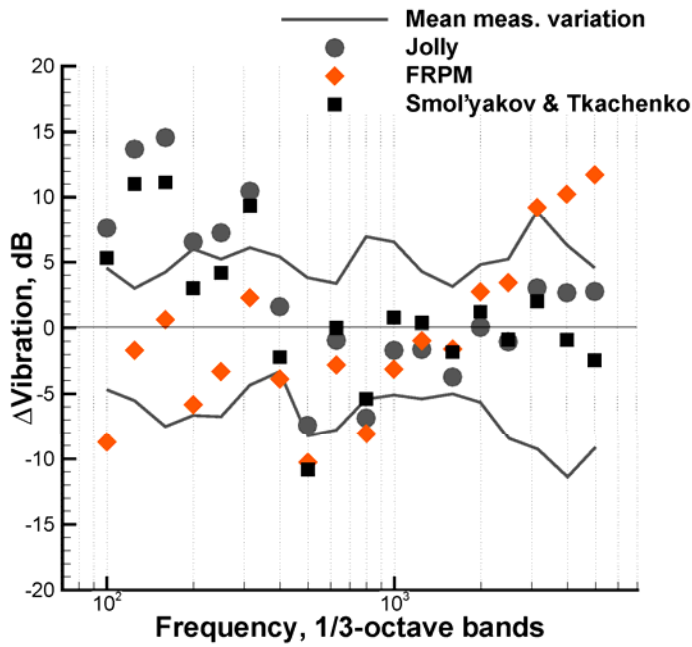
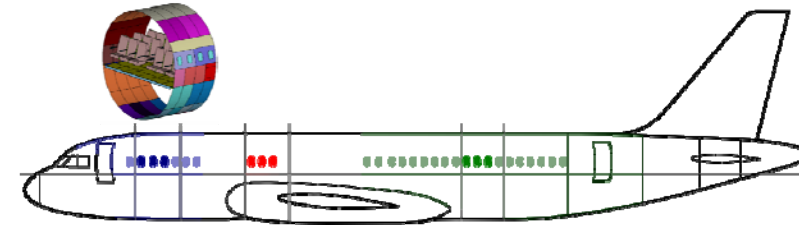


Constant Auto-Spectrum model



# Results & Outlook

## A320



Constant Auto-Spectrum model



## Results & Outlook

### Summary

- **Unique data base of in-flight measured TBL excitation in cruise flight conditions**
- **CFD calculations with TAU for A320 in cruise flight conditions (similar to flight tests)**
- **Semi-empirical auto-spectrum model adapted to measurements and based on CFD data, by including turbulence kinetic energy, pressure gradient...**
- **Full numerical approach to calculate auto-spectra as well as wavenumber-frequency spectra**
- **Testing of different literature wavenumber-frequency models**
- **Calculation of structural vibration with Grahams method and SEA for a flat plate**
- **Calculation of structural vibration of an Airbus A320 and validation with measured structural acceleration**



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# Results & Outlook

## Outlook

- Further developing of the auto-spectrum model towards higher pressure gradients in the cockpit region
- Further testing of numerical methods in high pressure gradient areas
- Application of methods to the whole Airbus aircraft family



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Thank you for your attention



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