CEAS-ASC Workshop ‘Future Aircraft Design and Noise Impact’, 6-7 Sep 2018, Amsterdam

# Fan noise due to boundary layer ingestion in novel aircraft architectures (activities within DLR project AGATA$^{3S}$)

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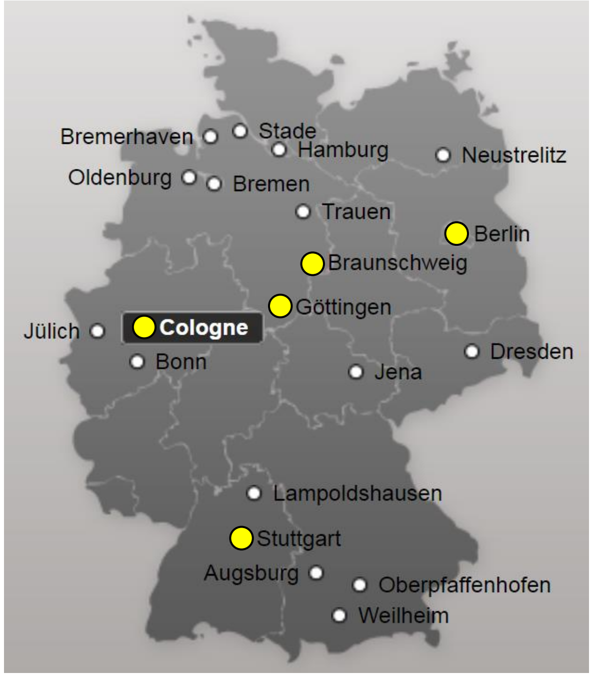
# DLR project AGATA$^{3S}$

## Impact of boundary layer ingestion on the aerodynamics, aeroelasticity, structural mechanics and acoustics of the aero engine fan

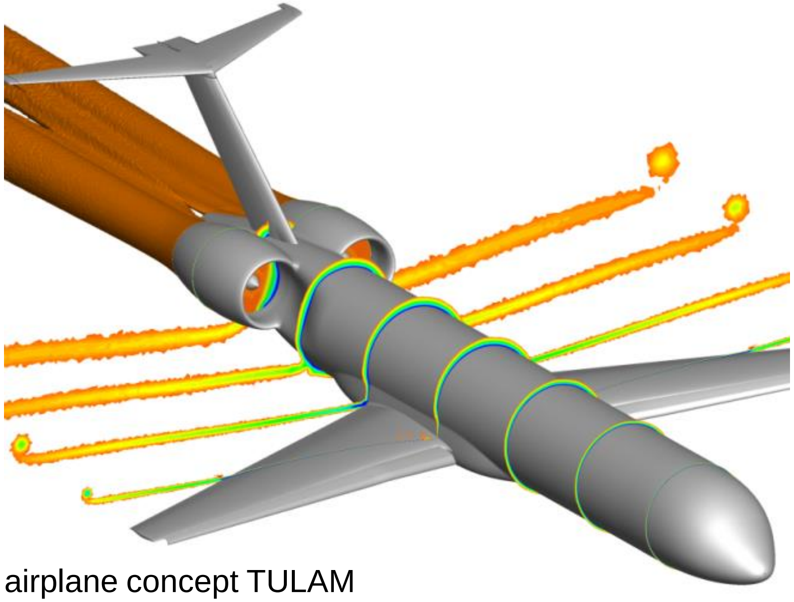
- Duration 2017-2020
- Institute of Propulsion Technology
  - Engine Acoustics
  - Fan and Compressor
  - Engine
  - Engine Measurement Systems
- Institute of Aeroelasticity
  - Aeroelasticity of Turbomachinery
- Institute of Structures and Design
  - Design and Manufacture Technologies
- Institute of Aerodynamics and Flow Technology
  - Transport Aircraft
  - Technical Acoustics



# Objectives of the project AGATA$^{3S}$

1. Assess the relevance of the aerodynamic, aeroelastic, structural and acoustic effects that are caused at the fan by BLI
2. Verify and enhance prediction methods and design tools
3. Identify technical approaches for the interdisciplinary optimization of the entire airplane-engine system

Investigations are related to aircraft of type A320 with engines embedded in the rear



airplane concept TULAM
(Toughen up Laminar Technology)

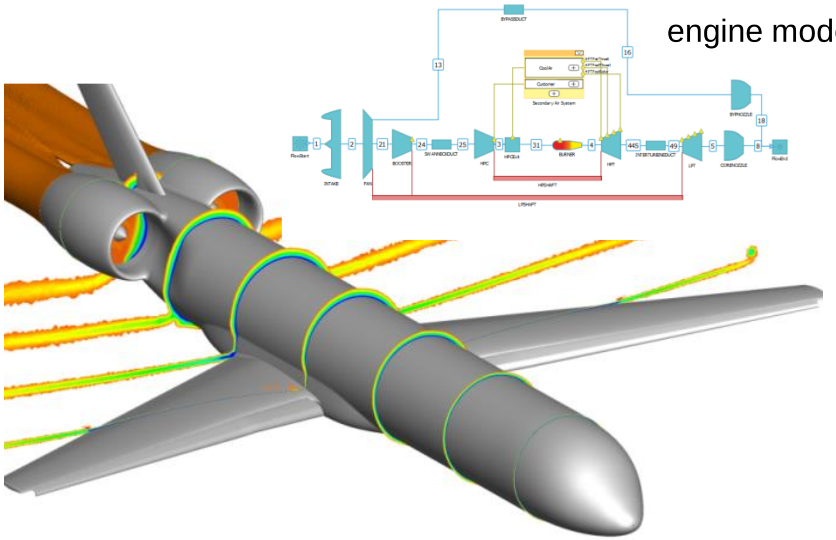
# Strategy to achieve objectives

**CFD modelling of BLI flow field of aircraft including engine nacelle and fan model for variable level of embedding**

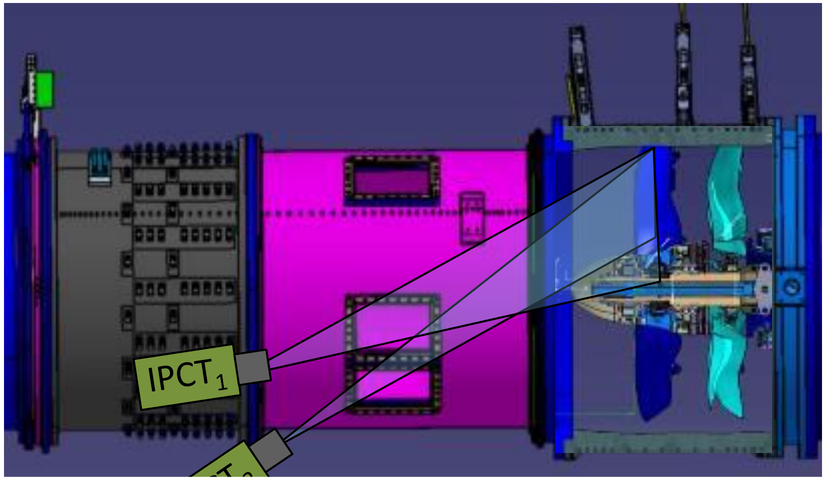
Reproduction of BLI in fan experiments under realistic conditions at DLR test facility

**Detailed analysis of all BLI effects at fan by comprehensive application of measurement techniques (hot wire, PIV, IPCT, BSSM, microphone arrays, …)**

engine model

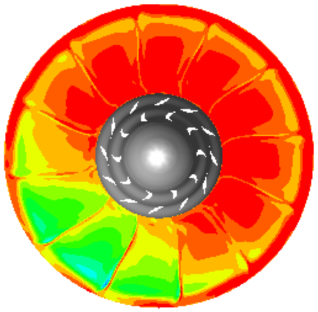


CFD: total pressure, 30% embedding, climb

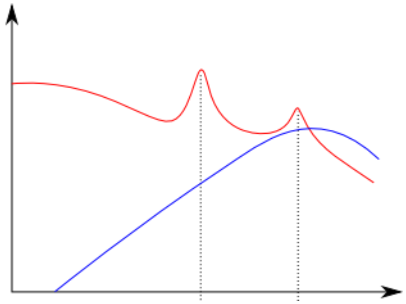



Experiment at CRISP2 Fan

# Strategy to achieve objectives



total pressure



noise generation

**Correlation analysis of BLI effects at fan with the relevant aerodynamic parameters**

Back transfer of findings to aircraft-engine system

**Assessment of trade-off between negative BLI effects and gained efficiency of aircraft**

**Identification of approaches for reduction of BLI effects at fan**

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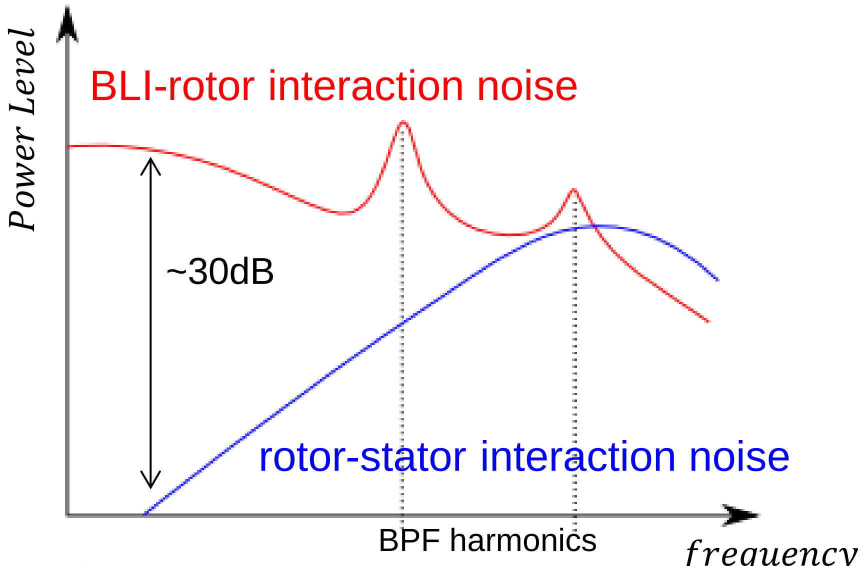
# Main goals of aeroacoustic studies

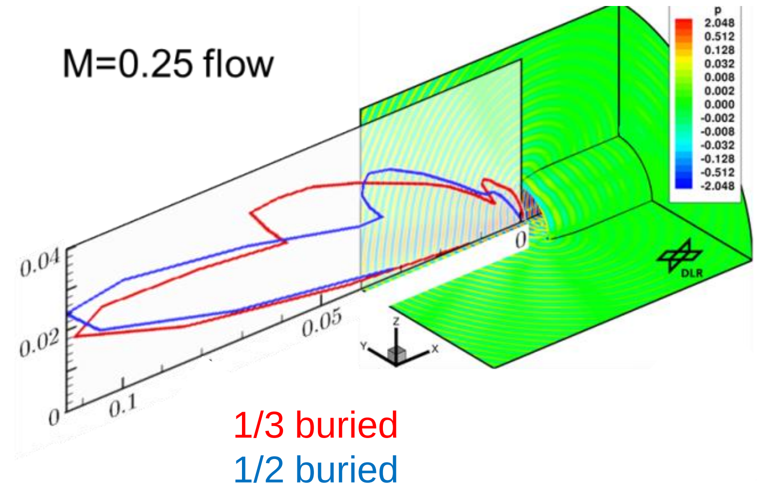
- Assessment of BLI-induced additional noise components of aero engine fan
- Detailed experimental analysis of the source mechanisms of BLI-fan-interaction noise
- Validation of numerical prediction codes

*broadband noise generation of turbo fan (prediction with PropNoise, qualitatively)*



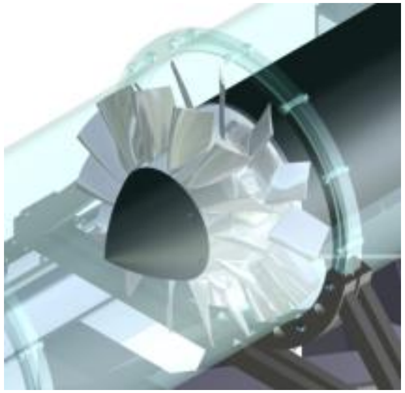

- Experimental study of sound radiation from embedded intakes, in particular propagation through boundary layer
- Validation of numerical prediction codes
- Appraisal of acoustic shielding effect due to the fuselage for aircrafts with rear mounted embedded engines

*intake buried in plate, plane wave radiation (CAA prediction)*

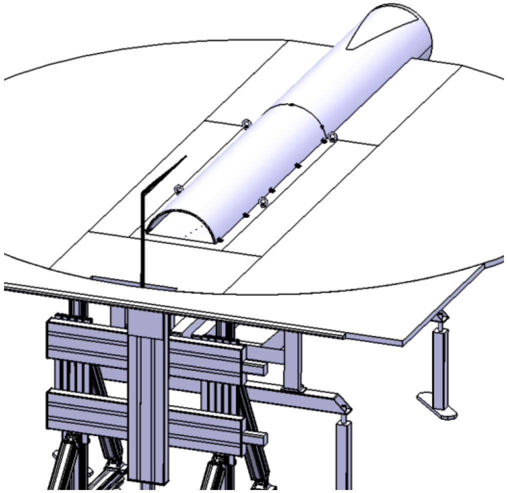


# Current project phase: conception of three experiments

Large scale tests
at CRISP2 fan
under realistic conditions



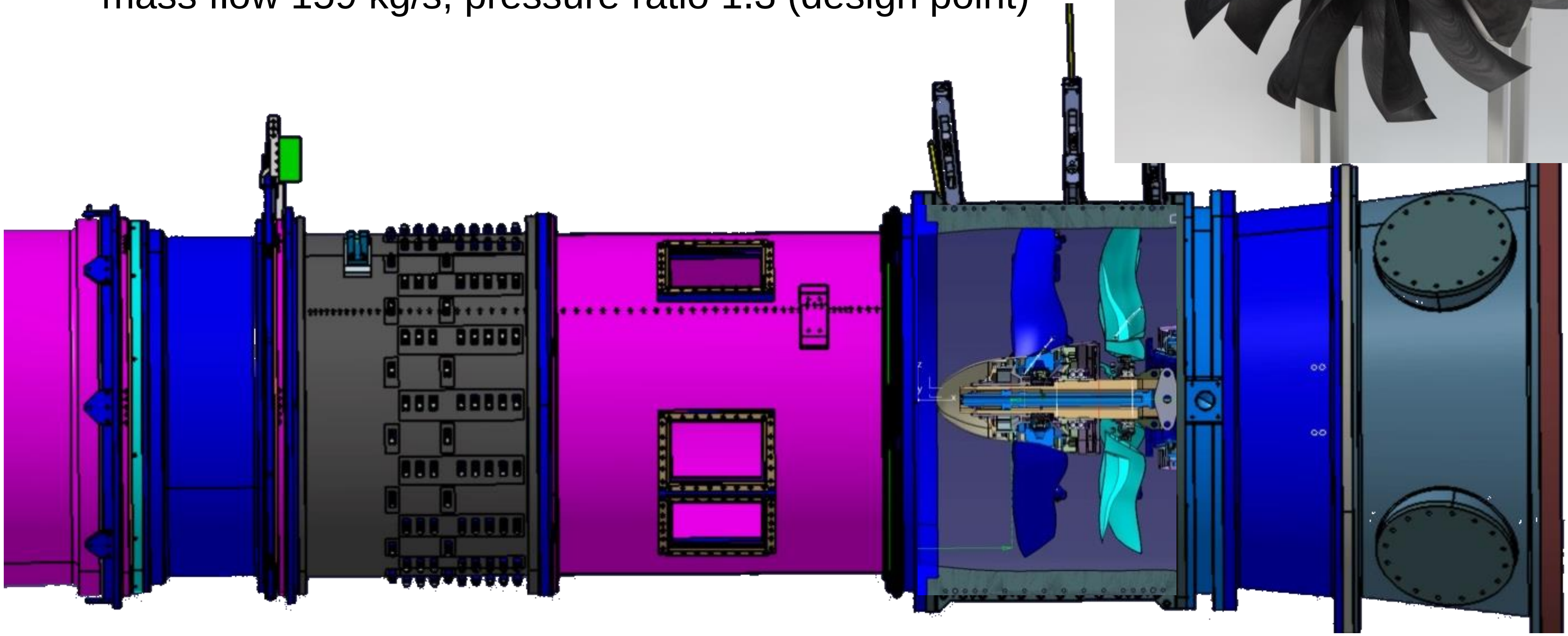
Small scale tests
at low-speed fan



Wind tunnel tests with
generic embedded
aeroengine intake

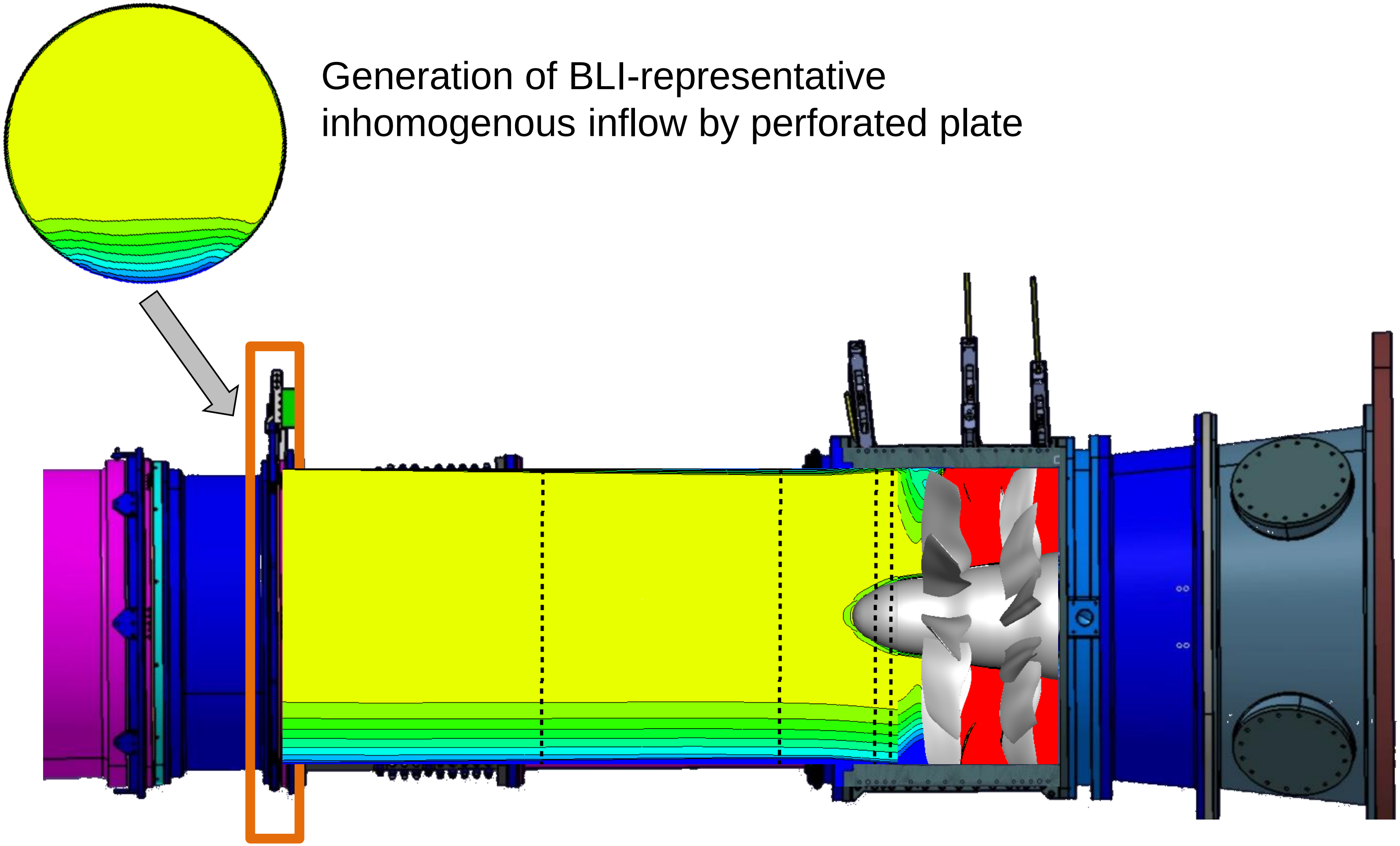
# Large-scale fan tests under realistic aeroengine conditions

- Compressor test bed M2VP in Cologne
- Counter Rotating Integrated Shrouded Propfan model CRISP2
  - diameter 1m, 10/12 rotor blades
  - bypass ratio ~16
  - mass flow 159 kg/s, pressure ratio 1.3 (design point)



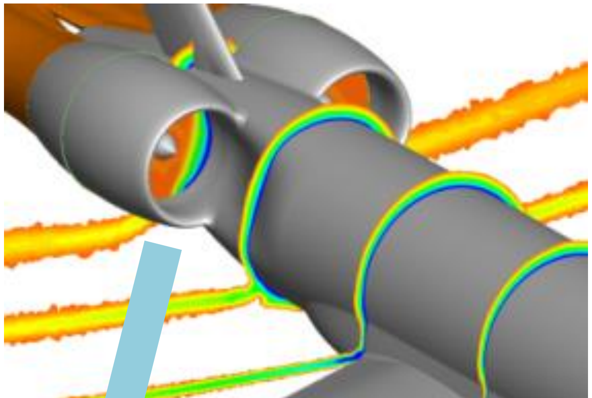
# Large-scale fan tests under realistic aeroengine conditions

Generation of BLI-representative inhomogenous inflow by perforated plate



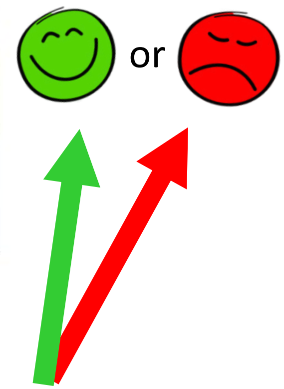
# Identification of feasible BLI cases for large-scale tests

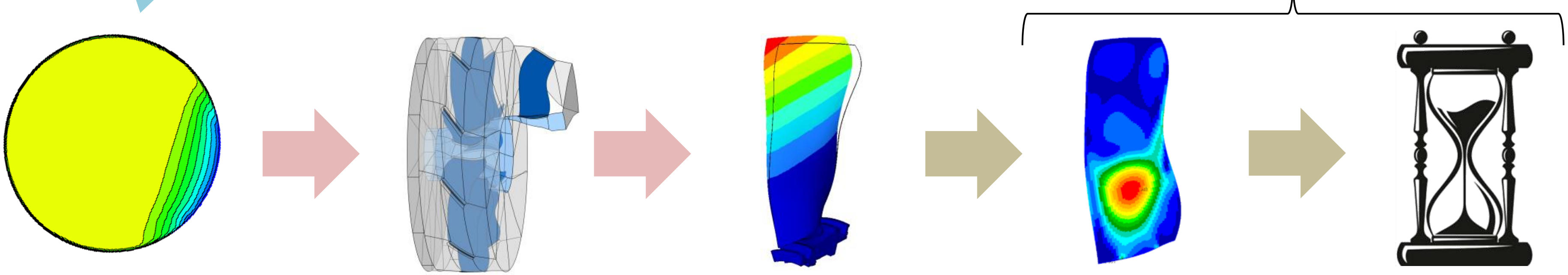
CFD simulations of variable engine embedding
and flight conditions



*transformation to*
*fan test rig conditions*

selection of BLI test cases
for fan rig test



BLI distorted inflow

unsteady pressure
distribution on blades

blade vibrations
blade stresses

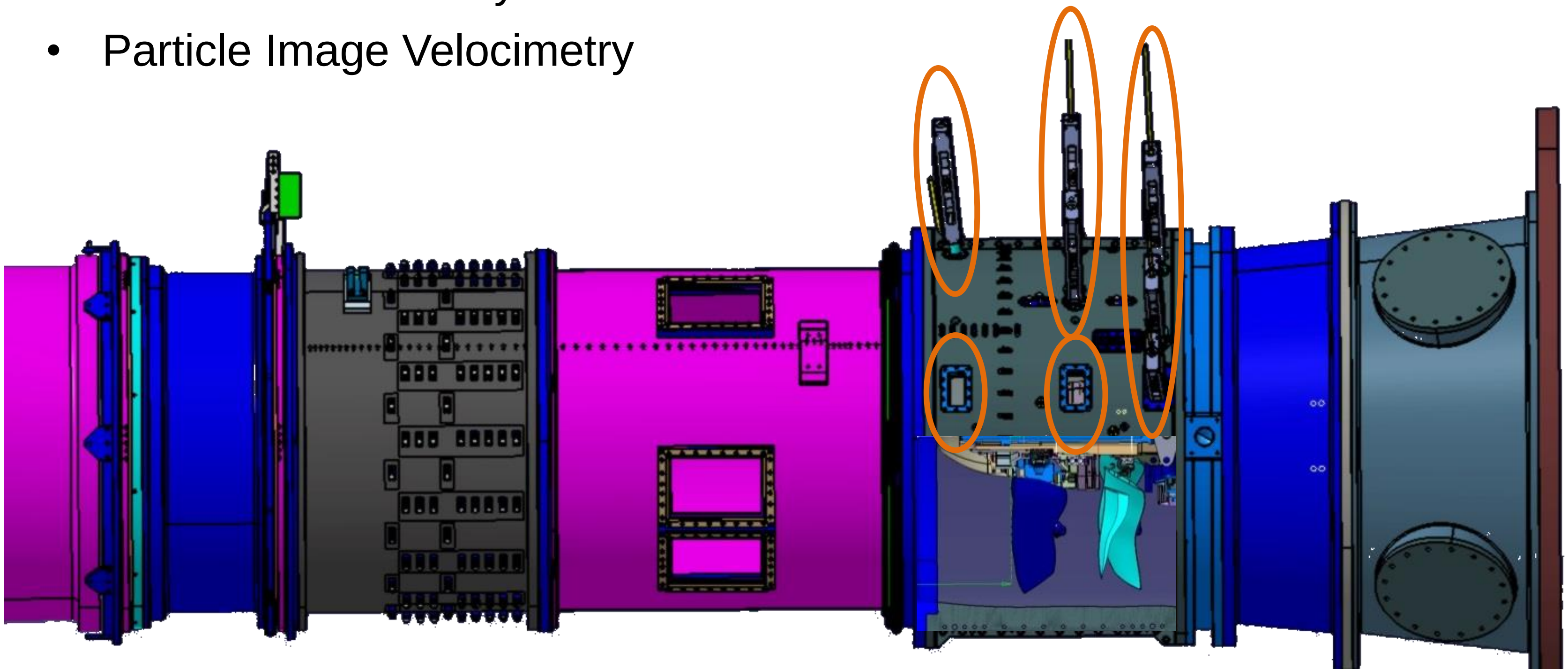
material strains
and elongations

material lifetime
estimate

# Large-scale fan tests under realistic aeroengine conditions

Comprehensive aerodynamic instrumentation for detailed measurement of steady and unsteady flow field upstream / interstage / downstream of fan

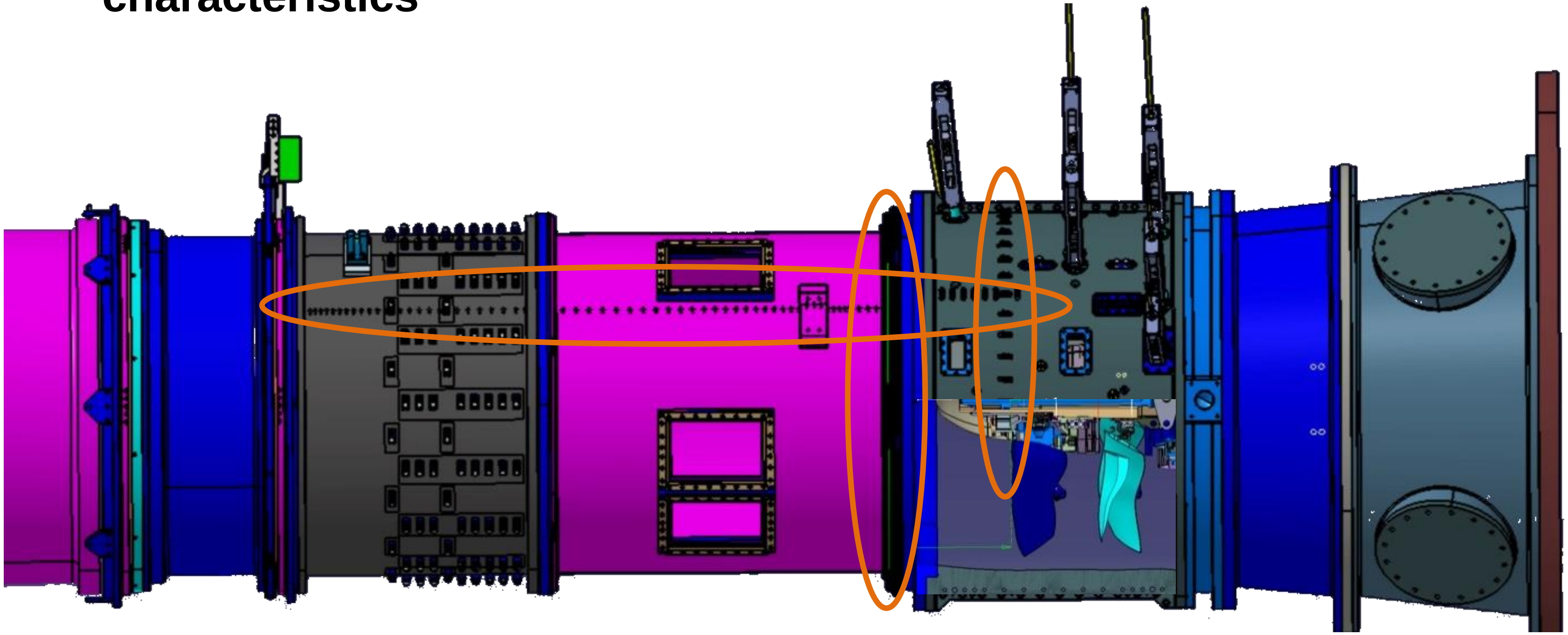
- Total pressure / temperature rakes
- Multihole pressure probes
- Hotwire anemometry
- Particle Image Velocimetry



# Large-scale fan tests under realistic aeroengine conditions

Comprehensive acoustic instrumentation with ~230 microphones

- Detailed resolution of tonal and broadband noise components by application of mode decomposition techniques
- Correlation with relevant aerodynamic influencing variables
- **Magnitude of BLI-induced noise depending on inflow distortion characteristics**



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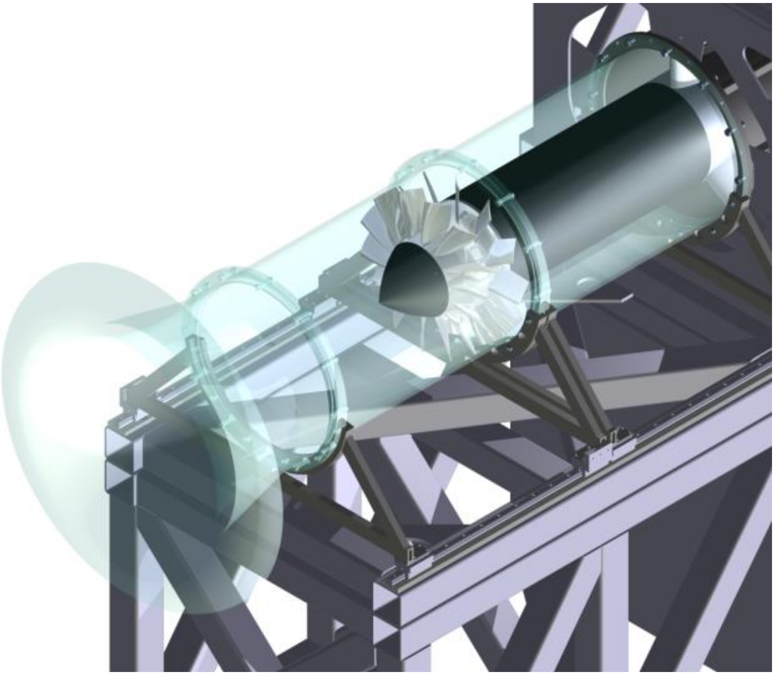
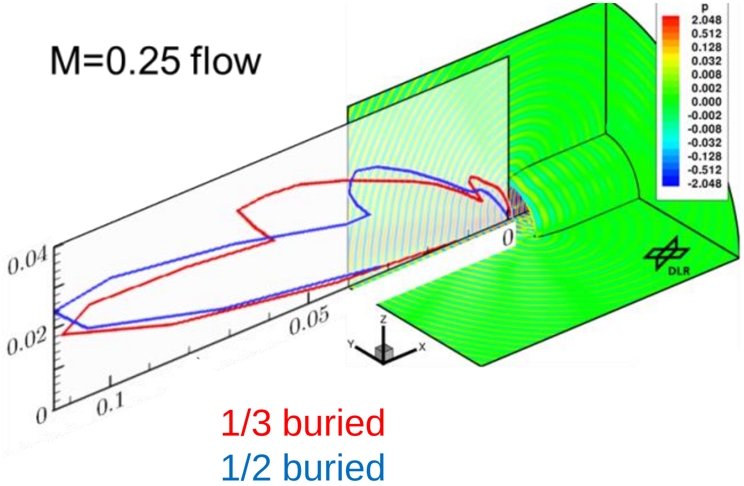
# Small scale tests at low-speed fan

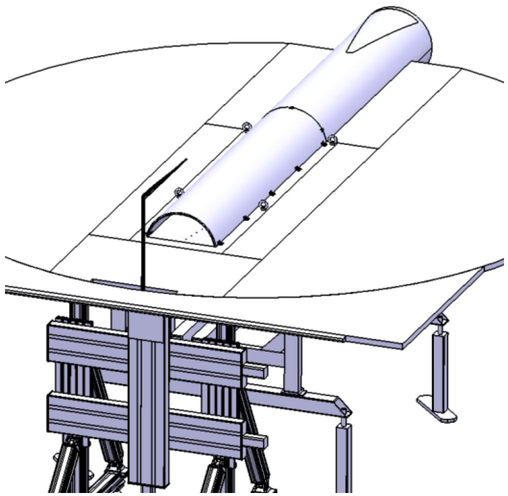
- Detailed analysis of BLI-impact on rotor-stator-configuration
- Comprehensive aerodynamic and acoustic measurements
- Application of acoustic source localization techniques
- Identification of complex dependencies of noise sources from velocity distributions through extensive test variations
- **Understanding of BLI-fan-interaction noise generating mechanisms**

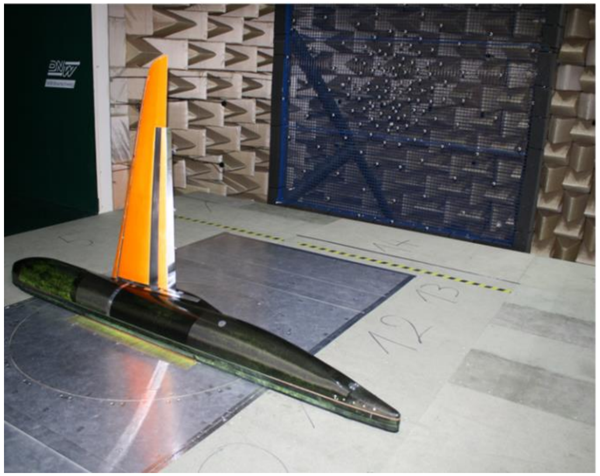


# Wind tunnel tests with generic embedded aeroengine intake for study of sound radiation effects

- Investigation of boundary layer impact on sound propagation, e.g. refraction effects
- Generic test set-up to enable accurate numerical simulation
- Validation of 3D CAA code Disco++ and of fast-multipole-BEM-method

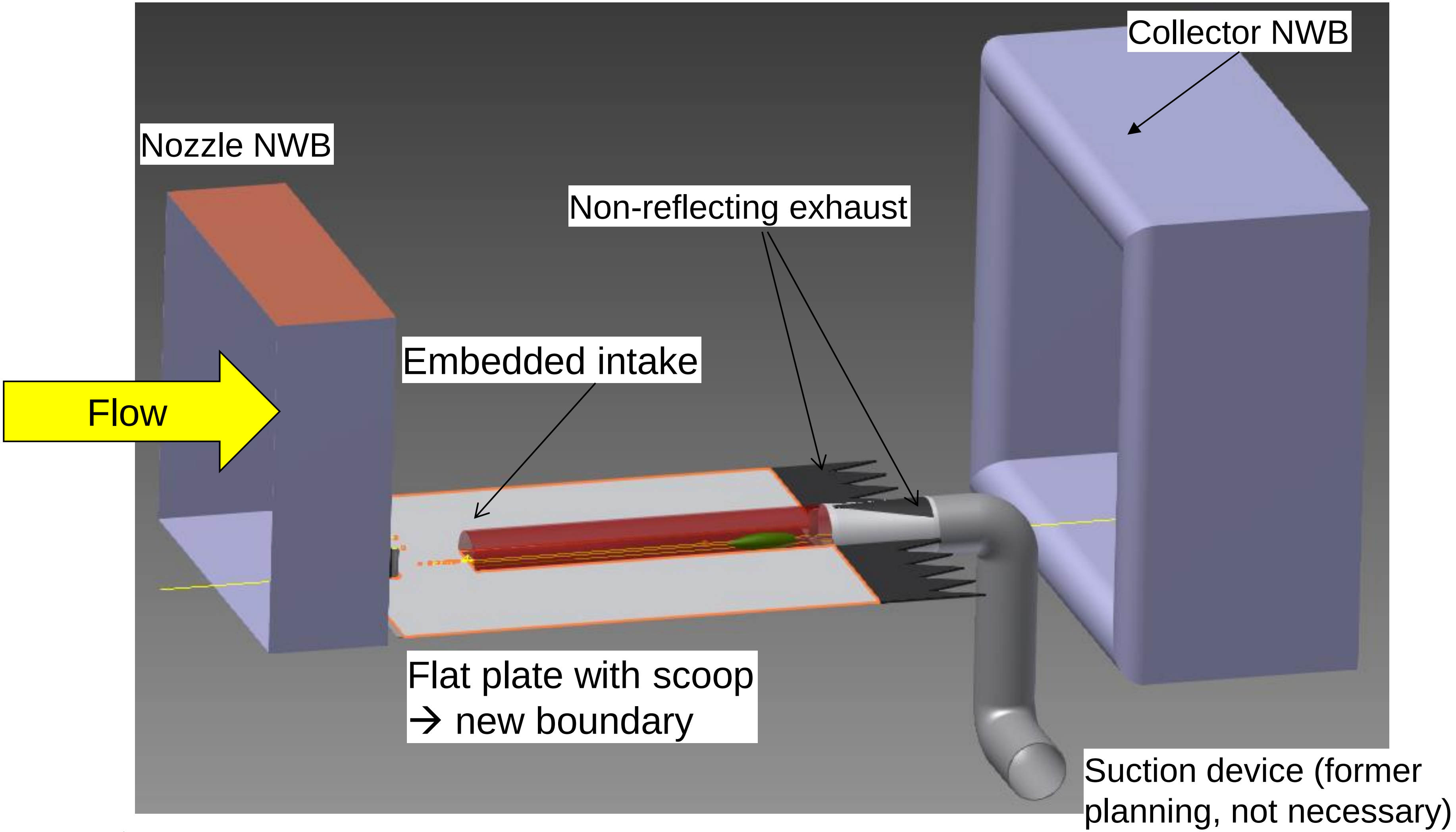


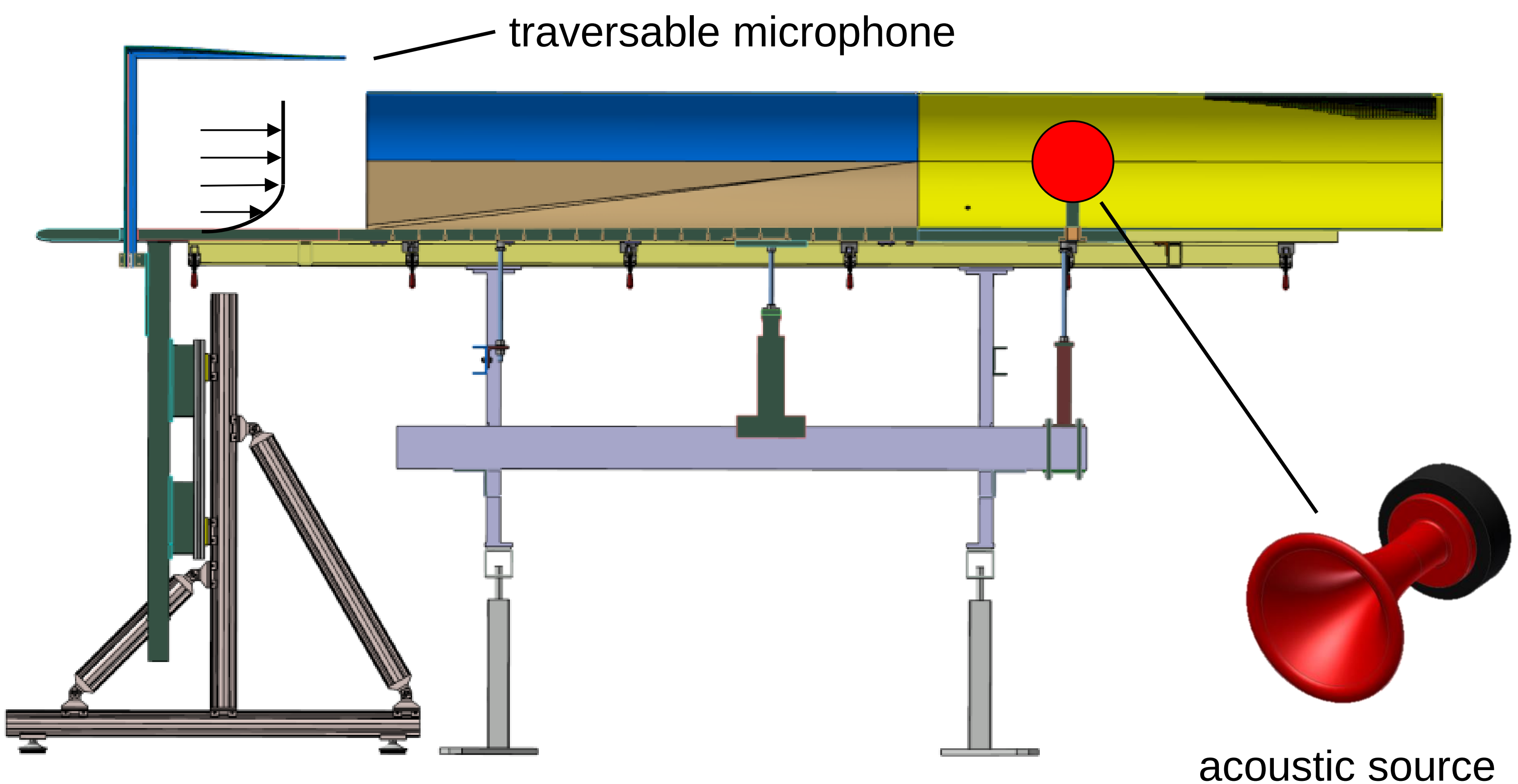


DNW-NWB wind tunnel

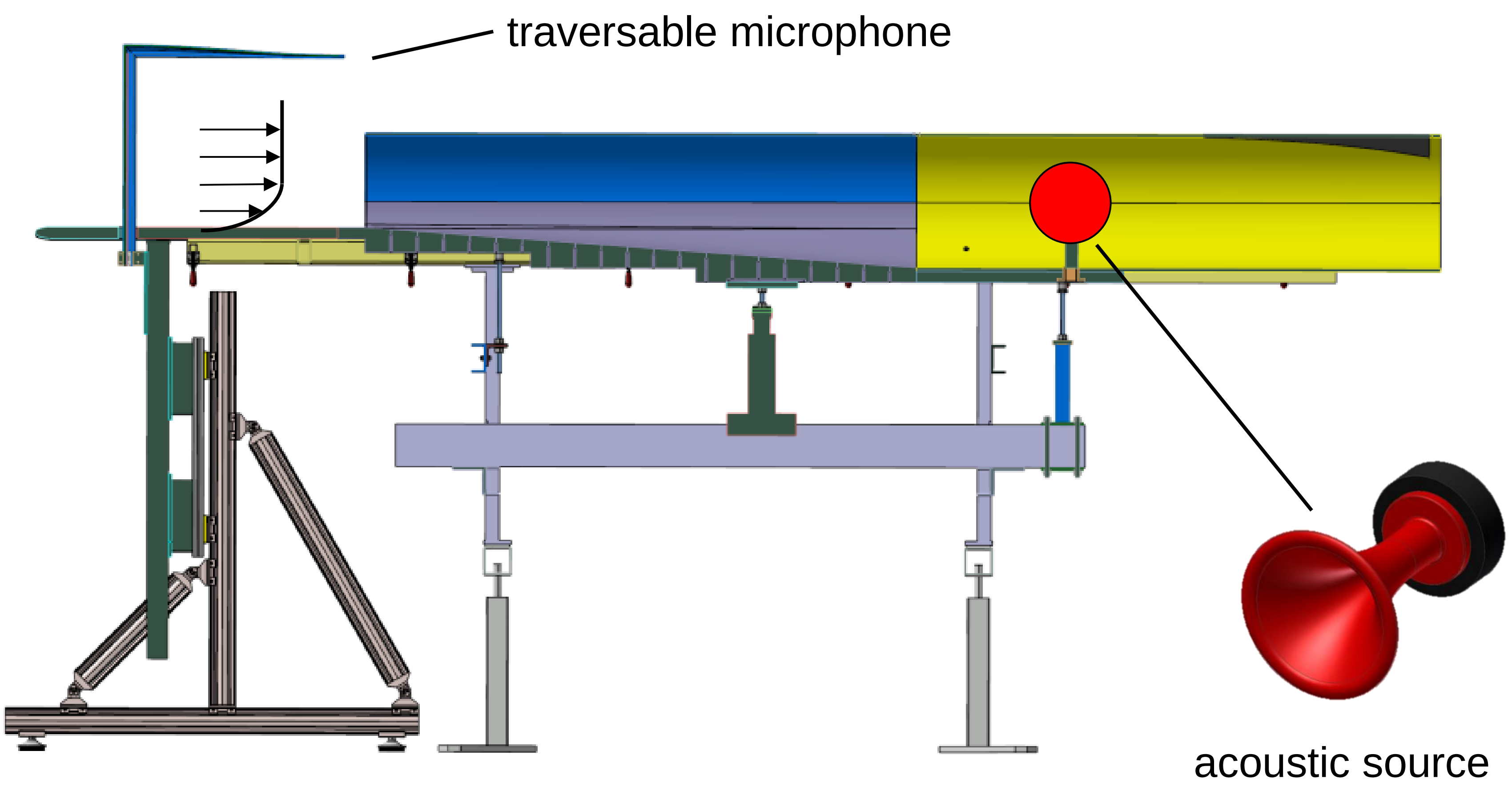
# Overview of test set-up in DNW-NWB wind tunnel



# Intake embedding 0% (flush with fuselage )

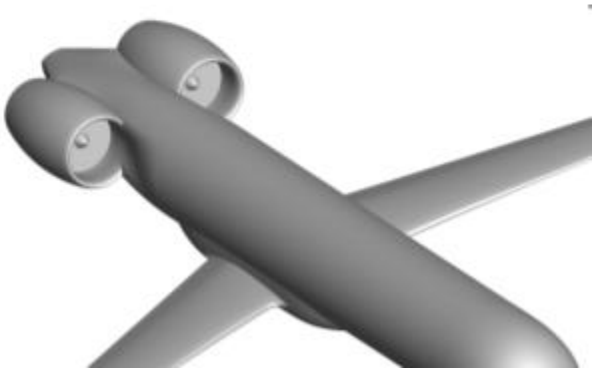


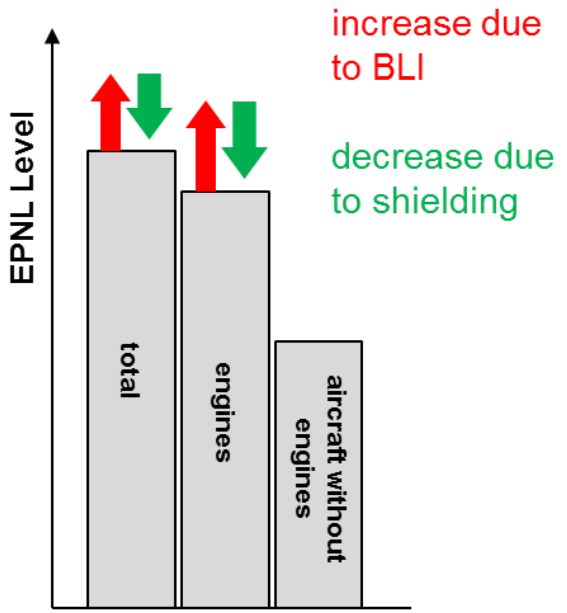
# Intake embedding 30%

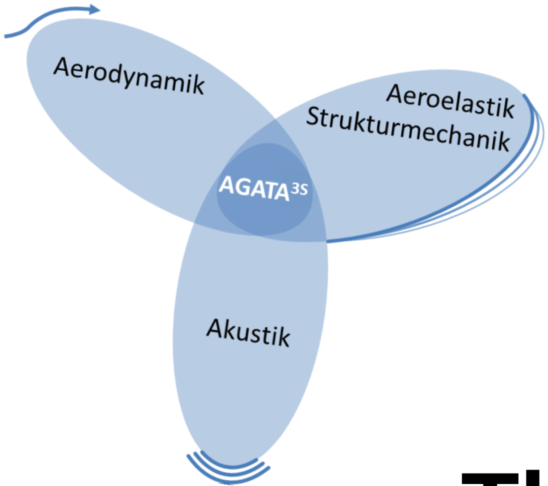


# Combination of acoustic studies at project end

- **Evaluate acoustic effects for aircraft** configuration with embedded engines using validated prediction methods
    - appraisal of fan noise generation
    - appraisal of the acoustic shielding effect
- **Estimate tradeoff** between
    - positive shielding effect
    - additional BLI-induced fan noise
- **Identify approaches for acoustic optimisation** of overall system










# Thank you for your attention