ONERA

THE FRENCH AEROSPACE LAB

retour sur innovation

Aeroacoustic Installation Effects on Transport Aircraft Research at Onera and DLR

Denis Gély*, Jan Delfs**

*) ONERA, Department DSNA, Aeroacoustics Unit ACOU, Chatillon, France

**) DLR, Institute Aerodynamics & Flow Technology, Technical Acoustics Unit, Braunschweig, Germany

DLR

Outline

- Introduction
- Source installation effects
  - Overview
  - Selected research results
- Acoustic installation effects
  - Overview
  - Selected research results
- Conclusions

ONERA
THE FRENCH AEROSPACE LAB

„Classical“ sources of exterior noise at aircraft

DLR

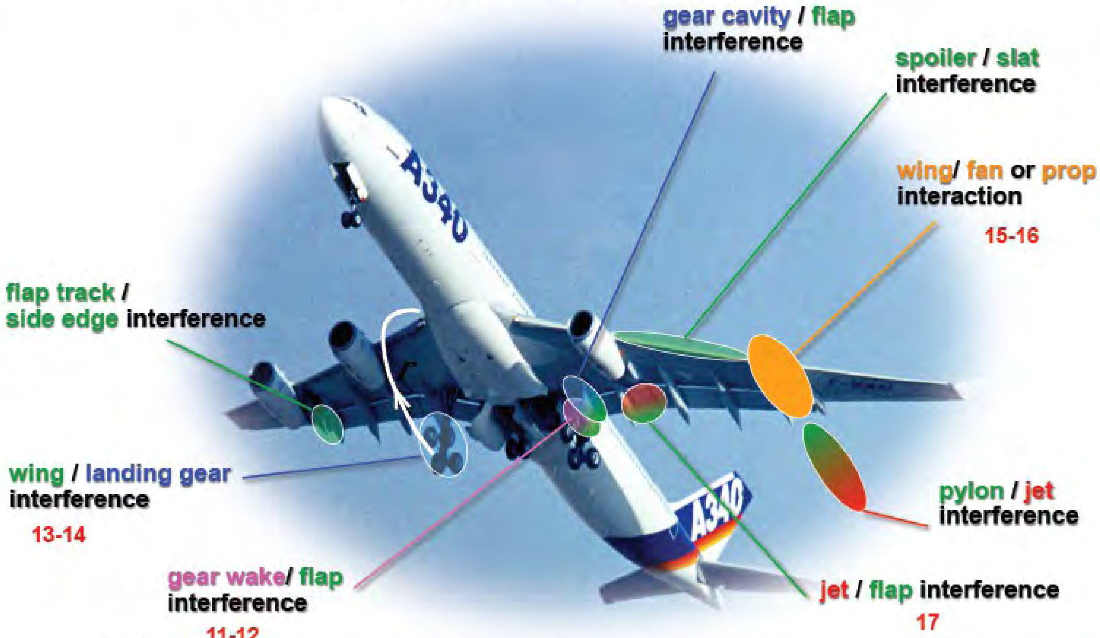
Introduction

- Definition of aero-acoustic installation effects
  - Source installation effects represent the change in, or the occurence of the aerodynamic **sound generation** of an aircraft component due to its attachment to the aircraft
    -typically accompanied by change in acoustic power-
  - Acoustic installation effects represent the change in the **sound radiation** of an aircraft component under the influence of the a/c geometry
    -typically not accompanied by change in acoustic power-

Source installation effects

ONERA
THE FRENCH AEROSPACE LAB

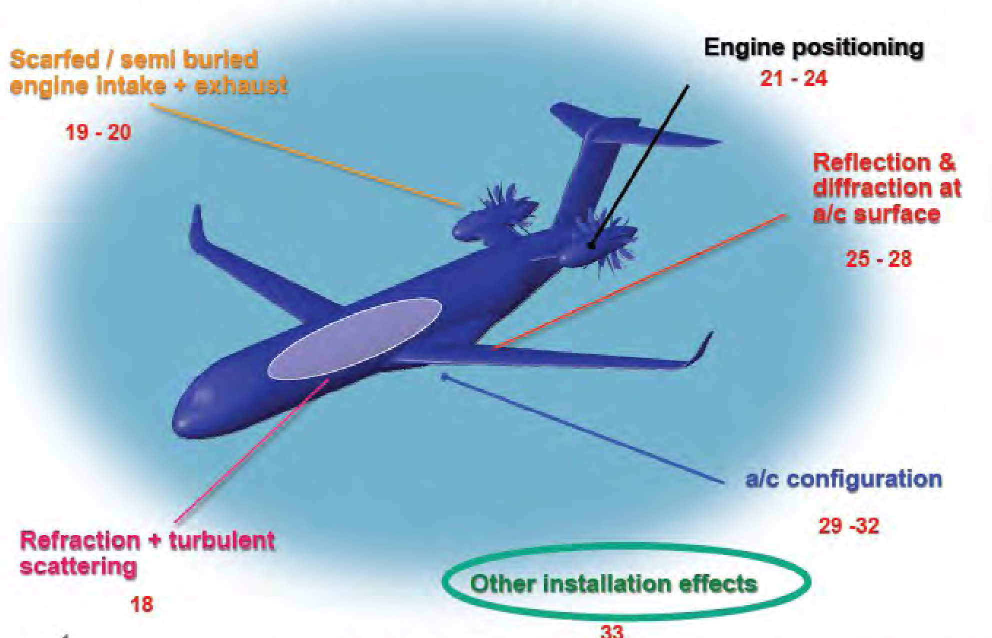
Installation sources of exterior noise at aircraft



DLR

Acoustic installation effects

Acoustic installation phenomena of exterior noise at aircraft



Conclusions

- There are more than the classical component related sources of aerodynamic noise on aircraft
- Installation affects sound generation + sound radiation
- So-called installation effects will become more important
  - Installation effects may be positive or negative
  - ACARE targets 2020 or 2050 not reachable without consideration of installation effects: a) avoid excess noise sources, b) exploit acoustic shielding and careful aerodynamic integration of components
- ONERA and DLR have started to engage in the field of installation aeroacoustics; more research is needed to predict installation effects incl. validation with experimental data.
- Low noise aircraft design requires reliable, affordable, non-empiric acoustic prediction as part of a multidisciplinary process for complete a/c
- …..as well as middle and large WT & Test facilities for experimental approach using more and more complex models and metrology

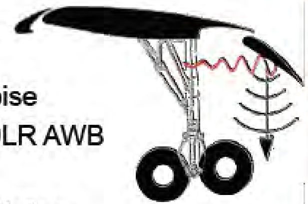
Thank you for your attention

The Authors Thank

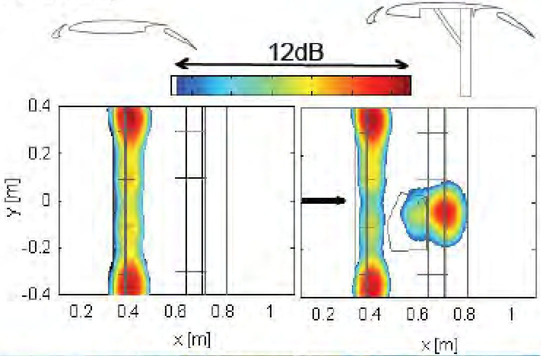
DLR : Oerlemans, M. Pott-Pollenske, R. Akkermans,
A. Stürmer, Dierke, Lufo, J. Brezillon, Lummer

Onera: E. Manoha, L. Sanders, S. Redonnet, C. Mincu,
T. Le Garrec, J. Bulté, A. Chélius

Gear wake / flap interaction



- Landing Gear wake flap interaction noise wind tunnel 1:13 scale model test in DLR AWB
- model scale landing gear noise not representative, but turbulent wake statistics (known from comparison with 1:1 scale) scale well
  ⇒ gear wake/flap interference noise representative!
- 6th power speed scaling ⇒ loading noise on flap
- Strongest source at flap leading edge (not flap trailing edge!)

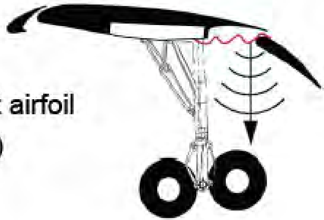


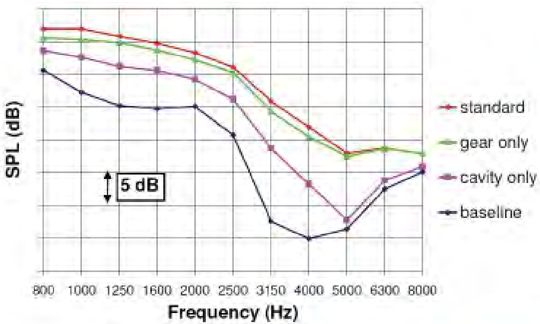
DLR

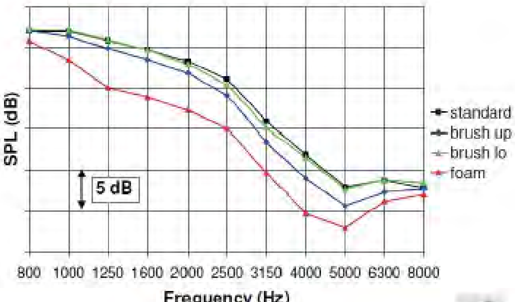
Oerlemans, Pott-Pollenske AIAA 2004-2886

Gear cavity wake / flap interaction

- Flap interference noise due to wake of LG-cavity alone (no LG) significantly higher than baseline high lift airfoil
- Flap interference source due to wake of LG (no cavity) considerably higher than due to cavity wake
- Significant noise reduction possible by porous metal foam insert into nose area of flap (less for brush extensions)





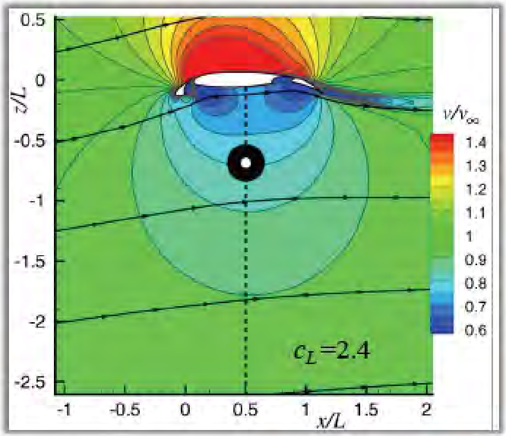


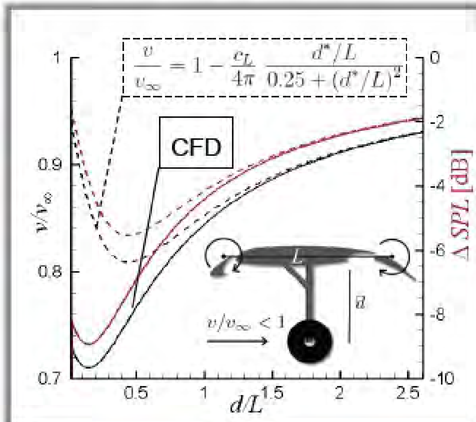
DLR

Oerlemans, Pott-Pollenske AIAA 2004-2886

Landing gear installation effects

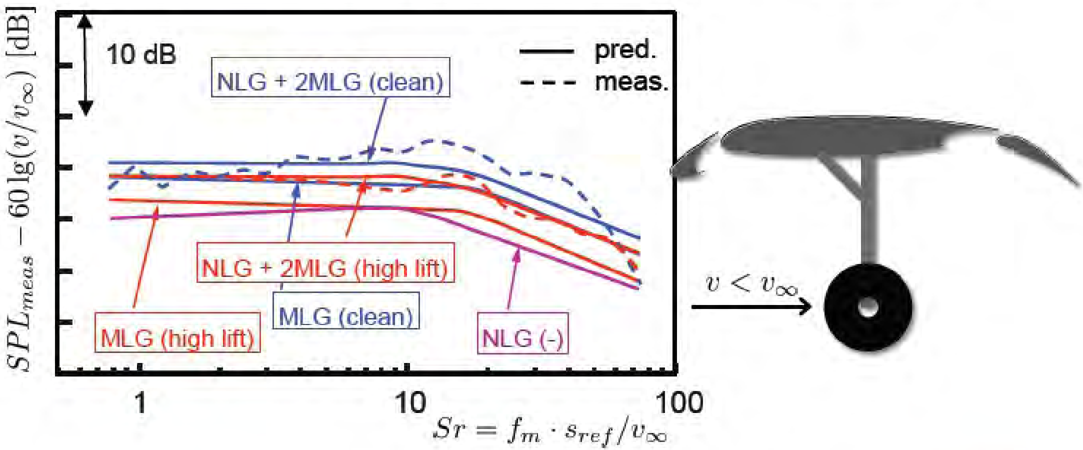
- Landing gears subject to flow different from freestream condition
  - Nose landing gear experiences slightly higher flow speed due to flow acceleration by fuselage nose section (usually weak)
  - Main (also body) landing gears below wings in high lift configuration





Landing gear installation effects

Flyover prediction/measurement A320 LG noise (overhead position)

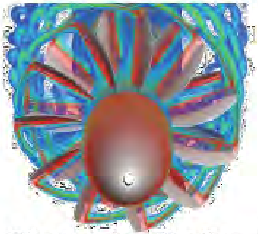


Reduced MLG noise for configuration “high lift” compared to “clean” for identical flight speed due to reduced local velocity for under the wing gear installation.

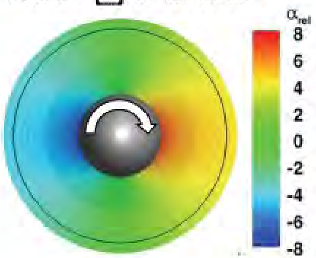
Source installation effects on Counter Rotation Open Rotor

flight Mach No. M=0.2, take-off

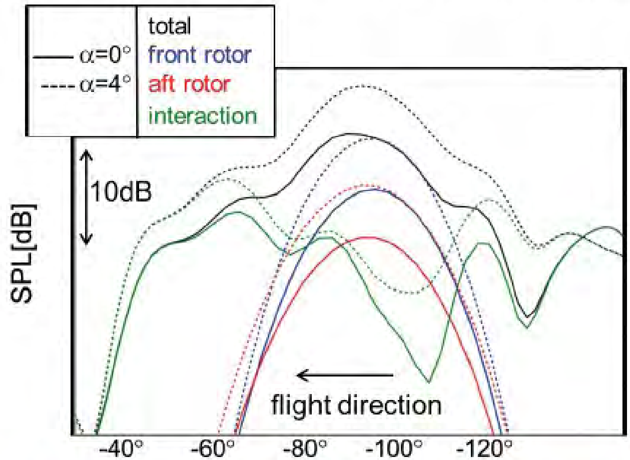
CFD: **TAU**
FW-H: **APSIM+**



Change in effective AoA at front rotor disk due to AoA=4° of CROR

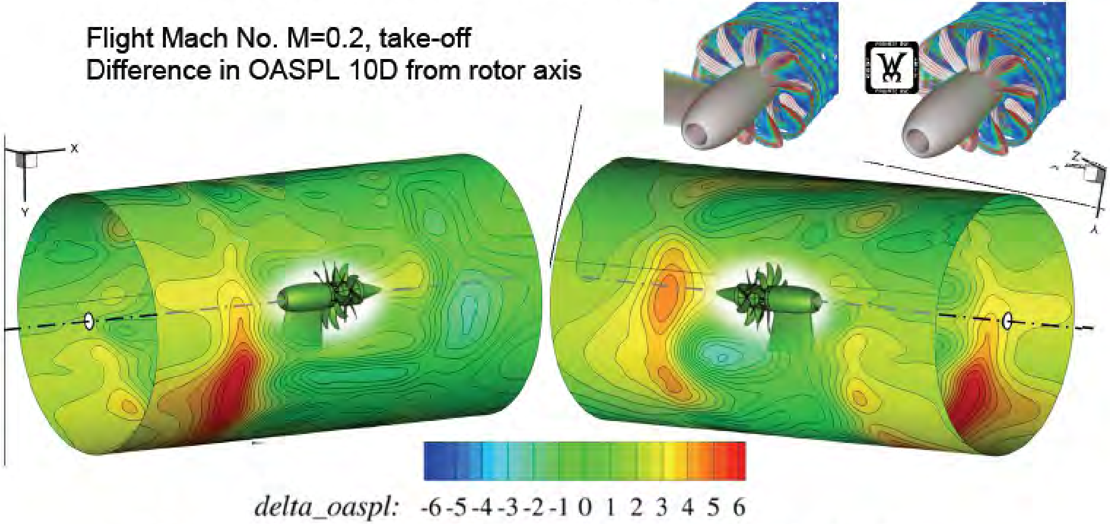


Farfield (10D) prediction along flyover line
flight Mach No. M=0.2, AoA- installation effect



Pylon effect on generation of CROR noise

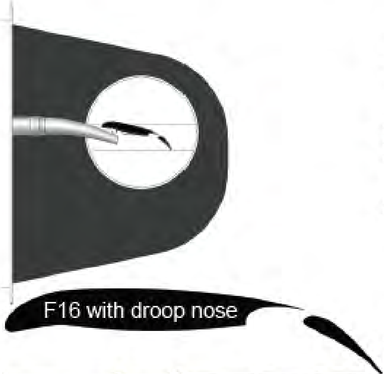
Flight Mach No. M=0.2, take-off
Difference in OASPL 10D from rotor axis

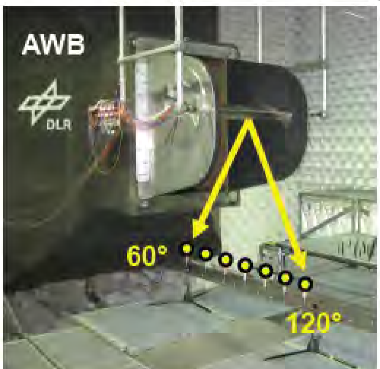


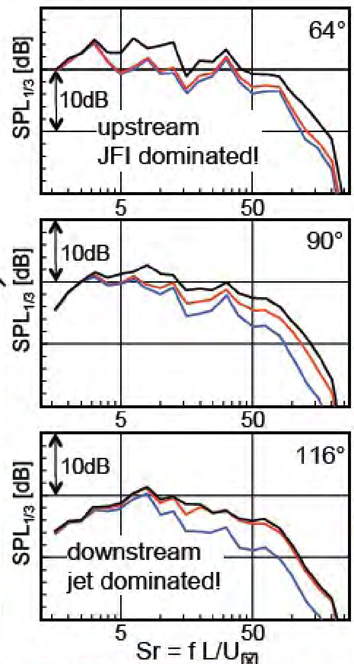
- 6.5dB increase upstream on front rotor downstroke side of pylon
- 4.5 dB increase downstream on rear rotor downstroke side of pylon

Importance of sense of rotation for installation at aircraft

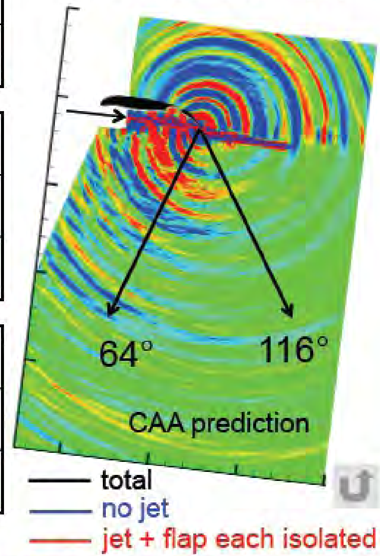
Jet flap interference (JFI)



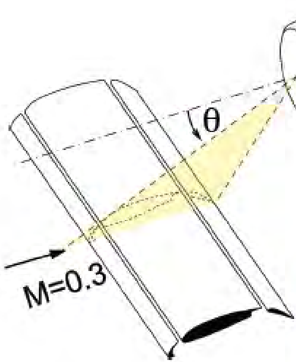


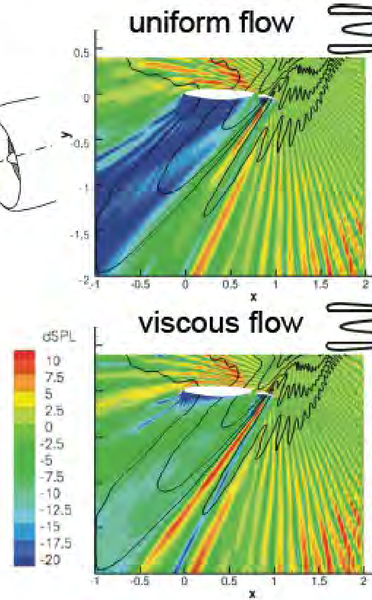


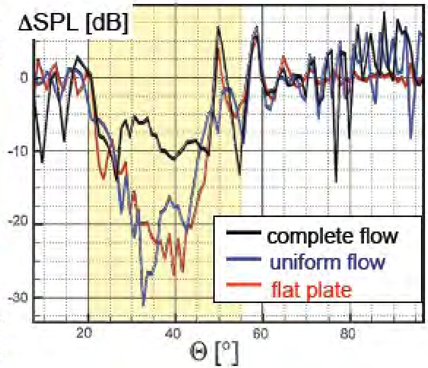
Flight speed U_{∞} = 60 m/s
Jet speed U_{jet} = 185 m/s
(cold single stream jet)



Unexpected installation effect on fan tones at High Lift Wing







Simplified flow assumption overpredicts shielding by 10dB!

Strong viscous flow effects on noise shielding even at low M

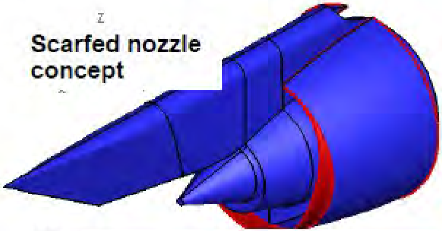
DLR

J. Dierke et al., AIAA 2010-3917

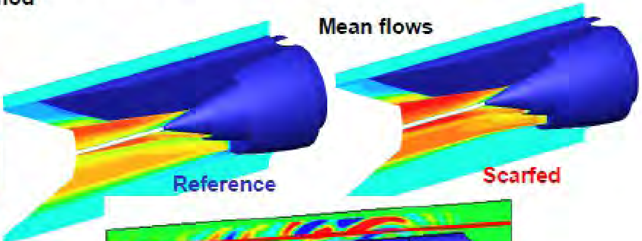
Source installation effect on fan noise
Scarfed nozzle (OPENAIR 2011)

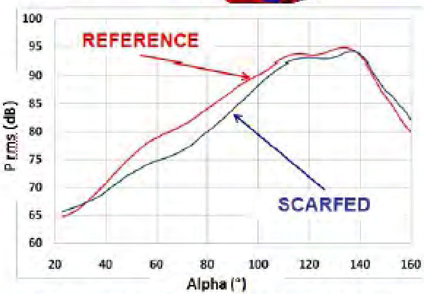
Hypothesis : acoustic broadband (all cut-on modes) emission at the fan Blade Passing Frequency
In-duct acoustic propagation : from fan plane to external surface : CAA solver sAbrinA-V0
Farfield acoustic radiation : Kirchhoff method

Scarfed nozzle concept

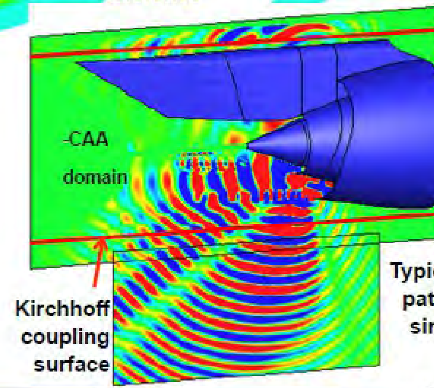


Mean flows



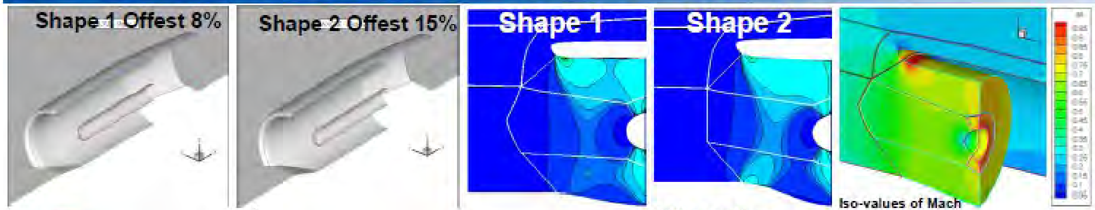


Farfield noise along a flyover path

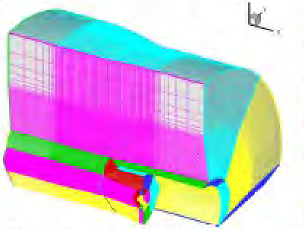


Typical acoustic pattern for on single mode

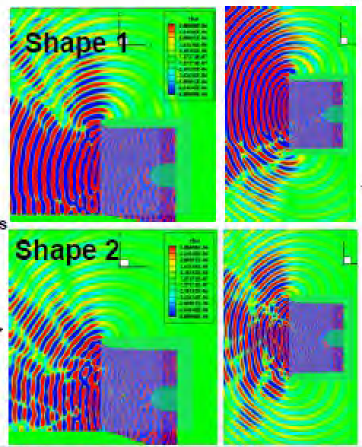
Source installation effect on fan noise for a semi-buried inlet using CAA (NACRE « Flying Wing » 2007)

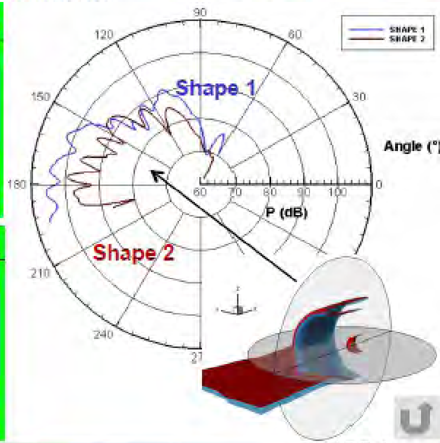


RANS mean flows



Multibloc structured grid for acoustics (only half-grid presented)



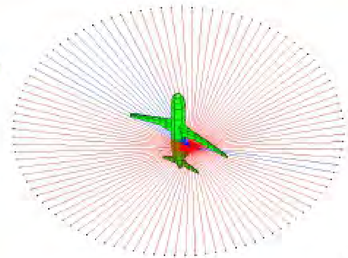


- Broadband fan noise emission (all cut-on modes) at BPF
- Instantaneous pressure in vertical and horizontal planes

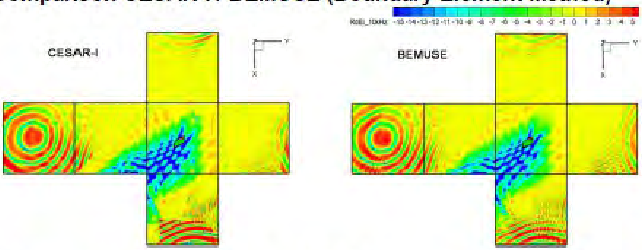
ONERA

CESAR-I code : Acoustical installation effect prediction

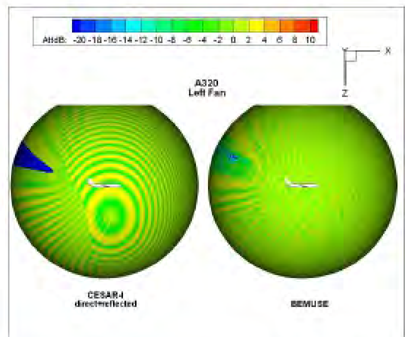
Main features Ray Tracing Method
Geometrical acoustic code for installation effect prediction
Acoustic field decomposed into direct / reflected / diffracted fields
<u>Advantages</u> : low computation cost, easy parallelization, acoustic field decomposition
<u>Drawbacks</u> : high-frequency approximation, geometry simplifications sometimes required
Computation on a U-tail geometry



Comparison CESAR-I / BEMUSE (Boundary Element Method)



Computation on a complete A320 geometry
Comparison CESAR-I / BEMUSE without diffracted / creeping rays
Current investigations
Need for accelerating creeping ray calculation
Validation on complete A320 geometry to be continued

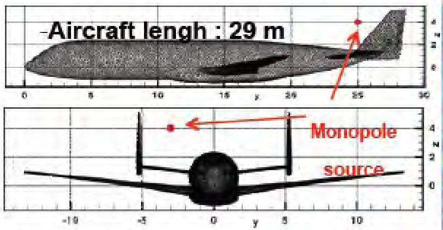


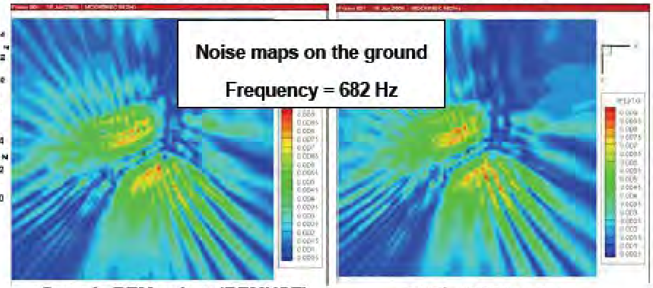
ONERA

ONERA/DLR cooperation MDORMEC (2009)

MDOrmec

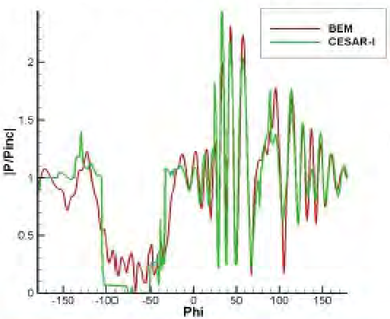
-Objective: aerodynamic/acoustic optimization of a turbofan installation in Rear Fuselage Nacelle configuration. Onera contribution: benchmark of BEM and Ray Tracing codes

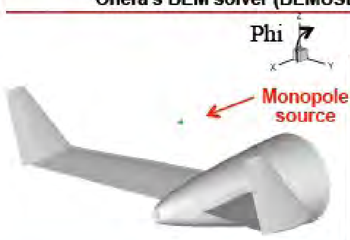




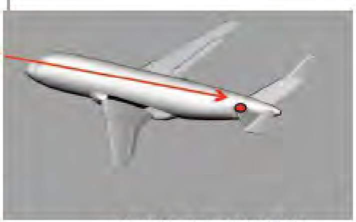
Onera's BEM solver (BEMUSE)

DLR' s BEM code



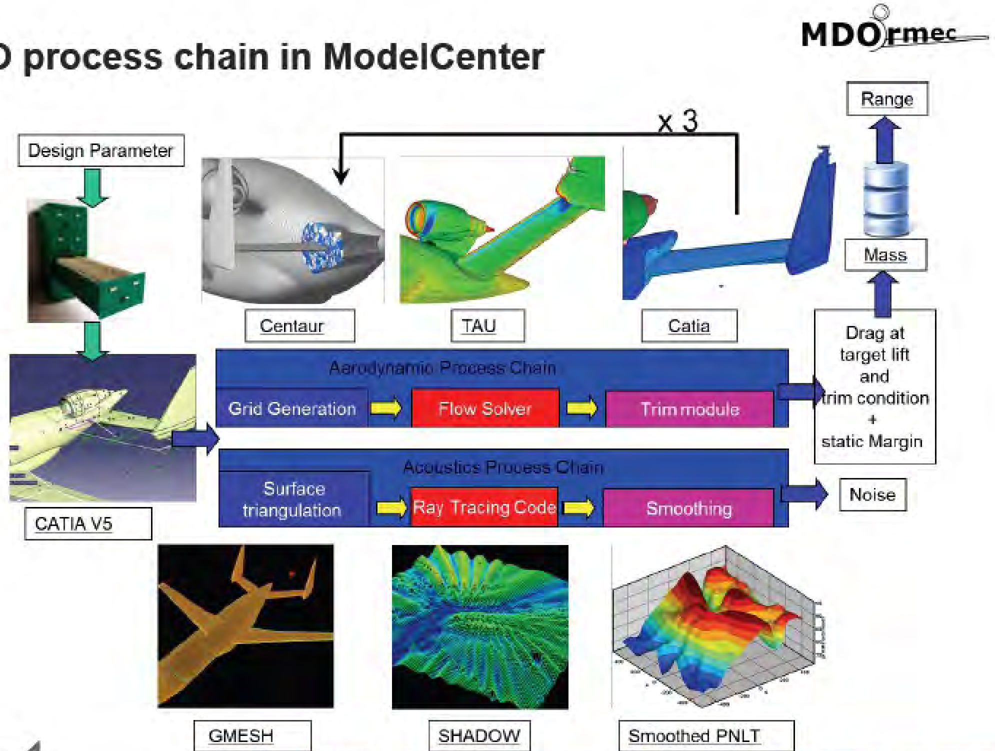


BEM (BEMUSE)



Ray Tracing (CESAR)

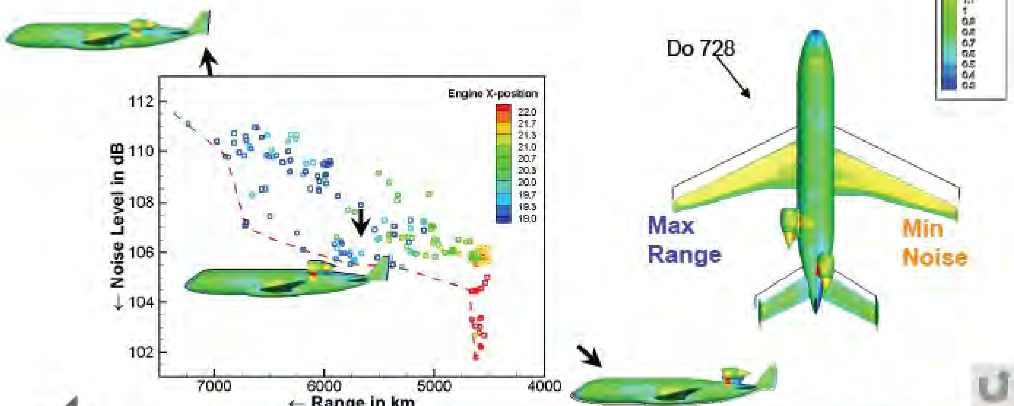
MDO process chain in ModelCenter



J. Brezillon et al, 8th AIAA MDO Specialist Conference 2012

Results

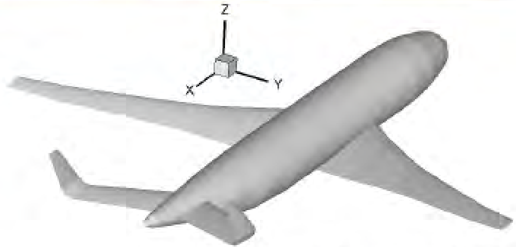
- Improvement of range implies an increase of noise level: there are non dominant solutions and Pareto front seems to exist
- The highest range is obtained with engine position as front as possible (lower drag, lower VTP weight) and relatively close to the wing (low pylon weight)
- The lowest noise level is obtained for engine position as aft as possible (maximize fan shielding effect)



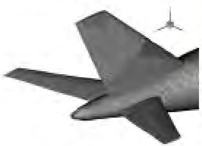
J. Brezillon et al, 8th AIAA MDO Specialist Conference 2012

Acoustic installation effect on fan noise
Using BEM (ROSAS-2004)

Turbo Powered fan Simulator (TPS)
In Rear Fuselage Nacelle configuration



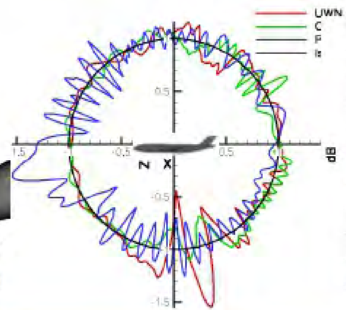
Complete aircraft (RFN)

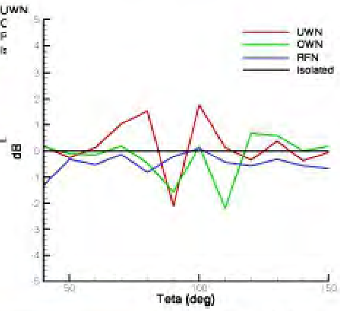


Under Wing Nacelle (UWN)

Over Wing Nacelle (OWN)

Rear Fuselage Nacelle (RFN)



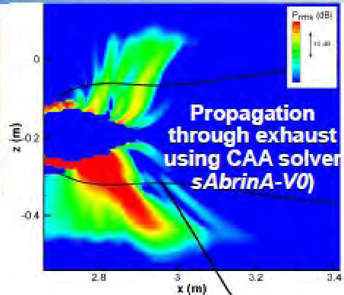


ONERA

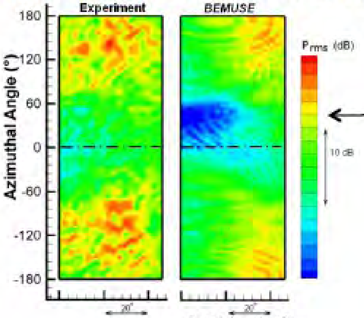
Acoustic installation effect on fan noise Using CAA/BEM (NACRE « Pro Green » 2007)

Circular array
54 Kulite sensors

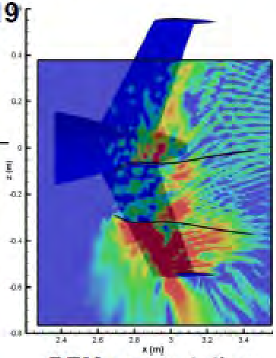
Injection of duct-acoustic modes



NACRE test set-up in CEPRA19

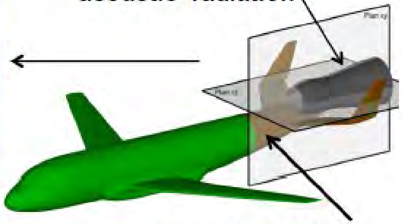


Farfield noise on a developed cylinder



BEM computation (solver BEMUSE)

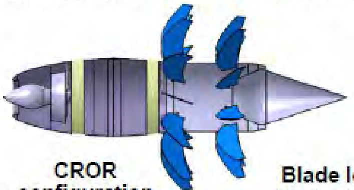
Surface of acoustic radiation



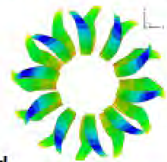
Acoustic scattering surface

Acoustic installation effect on CROR noise at low speed using BEM (JTI-GRA-5.3)

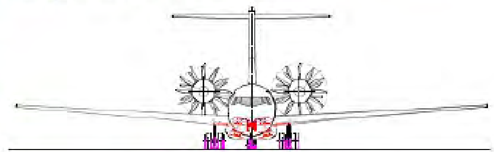
Objective: simulate CROR acoustic radiation in isolated and installed (on ALENIA aircraft) configurations
CROR noise source : blades load fluctuations via CFD (lifting line theory) using Onera's LPC2 solver
Acoustic installation effects : BEM solver BEMUSE, includinhg uniform flow effect



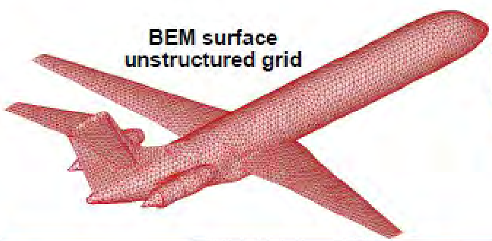
CROR configuration



Blade load fluctuations

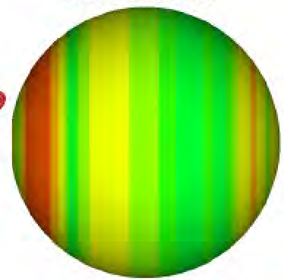


ALENIA aircraft configuration

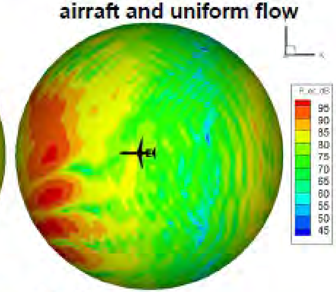


BEM surface unstructured grid

Isolated CROR



CROR installed on full airraft and uniform flow



First interaction tone BPF1+BPF2

ONERA

Aircraft acoustic installation effect on CROR noise at high speed using CAA (EC project CRESCENDO)

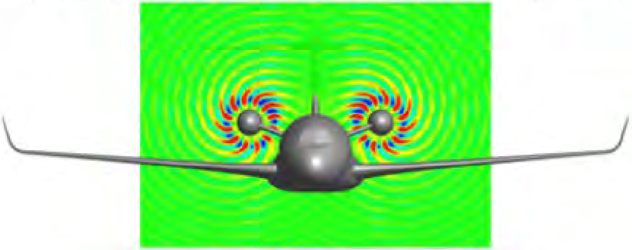
Objective: simulate CROR acoustic radiation in isolated & installed (generic Airbus) configurations

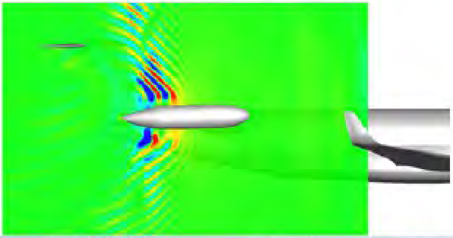
CROR noise source

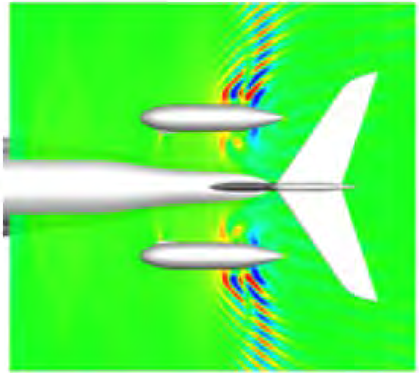
-Preliminary : quasi-analytical model based on circular rotating monopoles arrays

-Long term : unsteady CFD (uRANS) using contra-rotating domains (*elsA* solver)

-Acoustic propagation modelling : CAA solver sAbrinA-V0 on multiblock structured grid (Airbus/Onera cooperation) and non uniform mean flow (RANS computation by Airbus with solver *Tau*)



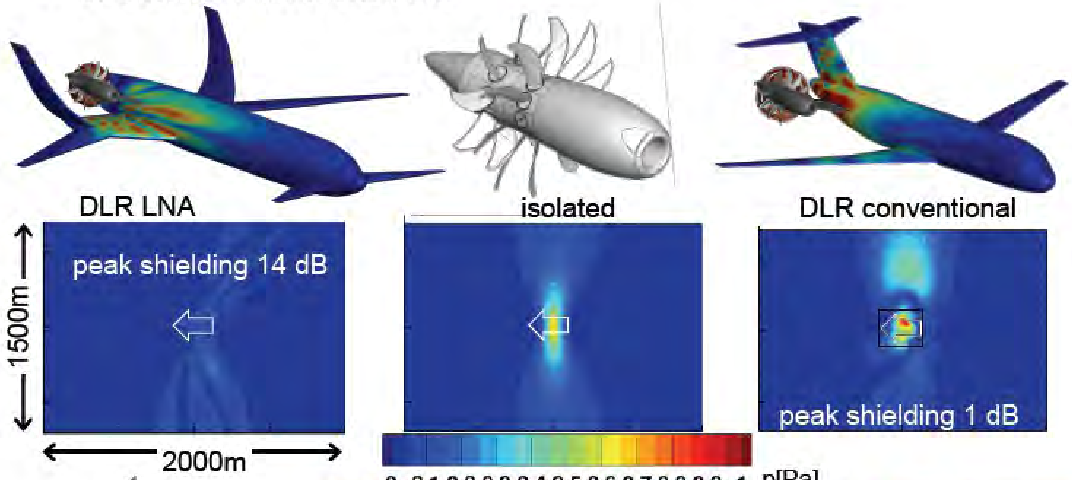




ONERA

A/C configuration / shielding of CROR sound

- Ray tracing approach fails for representation of largely extended sources, e.g. Counter Rotation Open Rotors
- Need complete solution to wave equation: Fast Multipole BEM code
- Shielding of rotor alone tone $BPF_{front\ rotor}$ =171.5 Hz
- SPL contours 120m below a/c

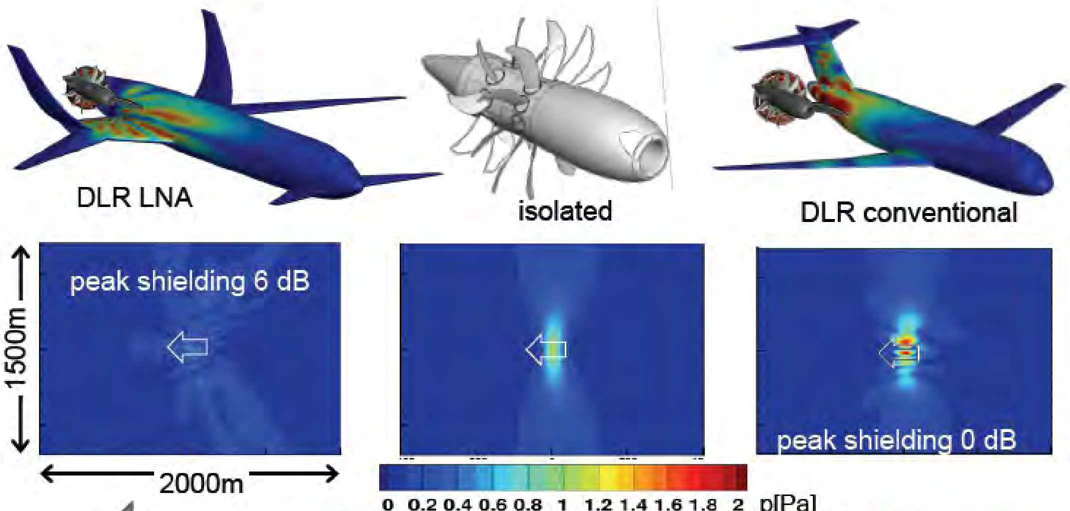


DLR

Lummer / DLR 2012

A/c configuration / shielding of CROR sound

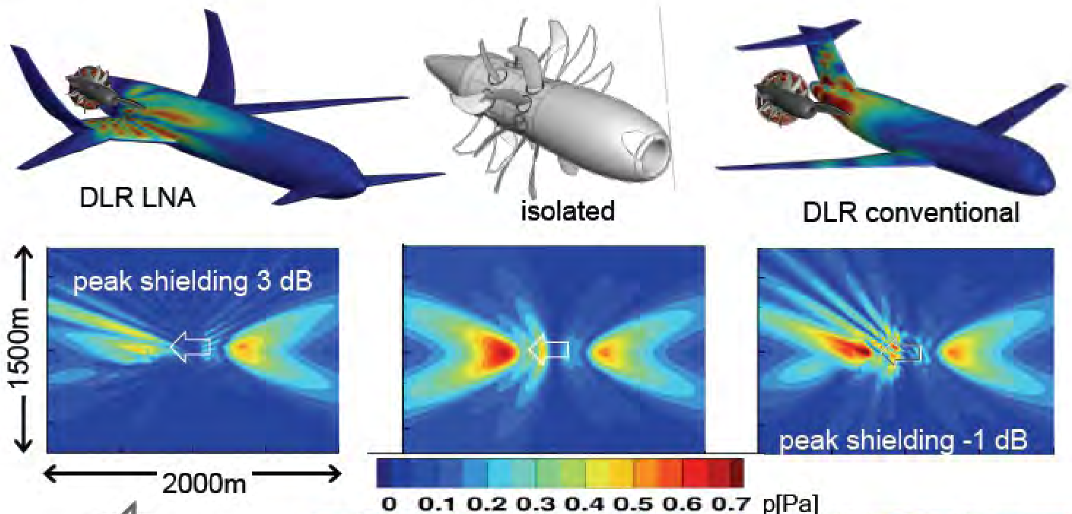
- Shielding of rotor alone tone $BPF_{rear\ rotor}$ =137.0 Hz
- SPL contours 120m below a/c



Lummer / DLR 2012

A/c configuration / shielding of CROR sound

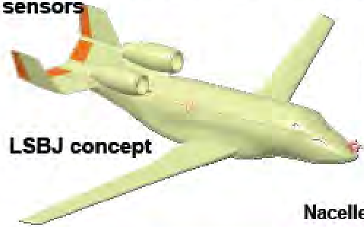
- Shielding of interaction tone $BPF_{rear} + BPF_{rear}$ =308.5 Hz
- SPL contours 120m below a/c



Lummer / DLR 2012

Acoustic installation effect on fan noise
Turbofan in RFN position on LSBJ (JTI-SFWA-224 - 2012)

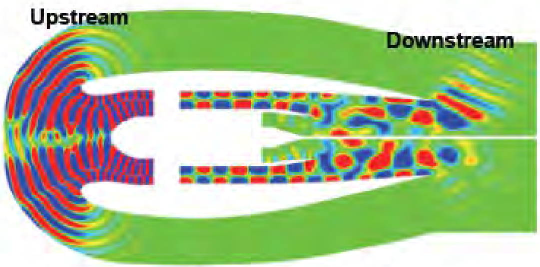
Concept : Dassault-Aviation (Low Speed Business Jet platform , to be tested in DNW (scale 1:4.5)
Onera contribution : simulate the shielding effect on fan noise (nacelle inlet & nozzle) using CAA and BEM
Preliminary objective : use noise prediction from isolated nacelle to position internal arrays of pressure sensors



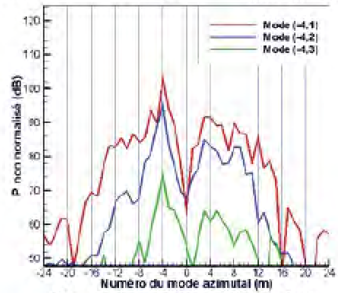
LSBJ concept

Nacelle CAO with possible positions of circular sensor arrays

3D RANS mean flow computation



In –duct propagation in upstream and downstream direction for acoustic modes (-4, 1) (-4, 2) (-4, 3)



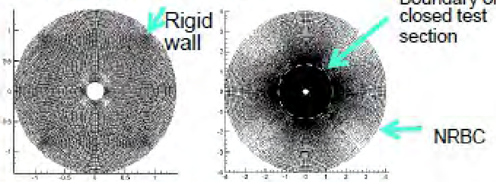
Simulation of modal detection for a given sensor array

ONERA

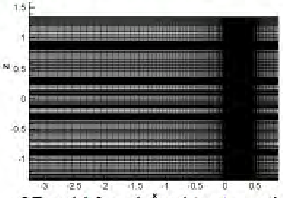
Wind tunnel acoustic installation effect on CROR noise at high speed using CAA (EC project NINHA)

Objective: simulate CROR acoustic radiation in isolated & installed (TSAGI high speed WT) configurations
CROR noise source : quasi-analytical model based on circular rotating monopoles arrays
Acoustic propagation modelling : CAA solver *sAbrinA-V0* on multiblock structured grid and non uniform mean flow (RANS computation by Onera with elsA)

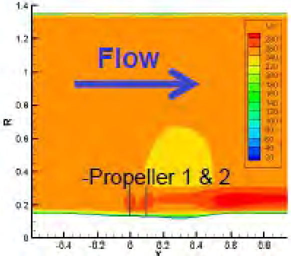
TSAGI T07 Wind Tunnel



2D grids for closed (left) and open (right) test sections

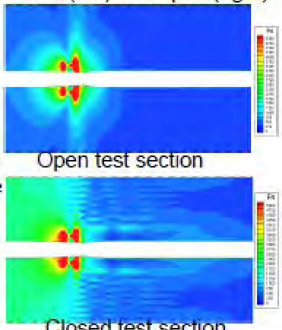


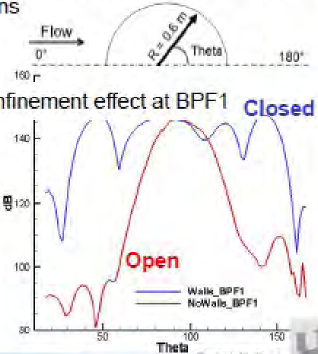
3D grid for closed test section



Axisymmetric RANS mean flow

RMS acoustic pressure





ONERA