# Sinus For Ever

# 30 ans de simulation et optimisation aérodynamique

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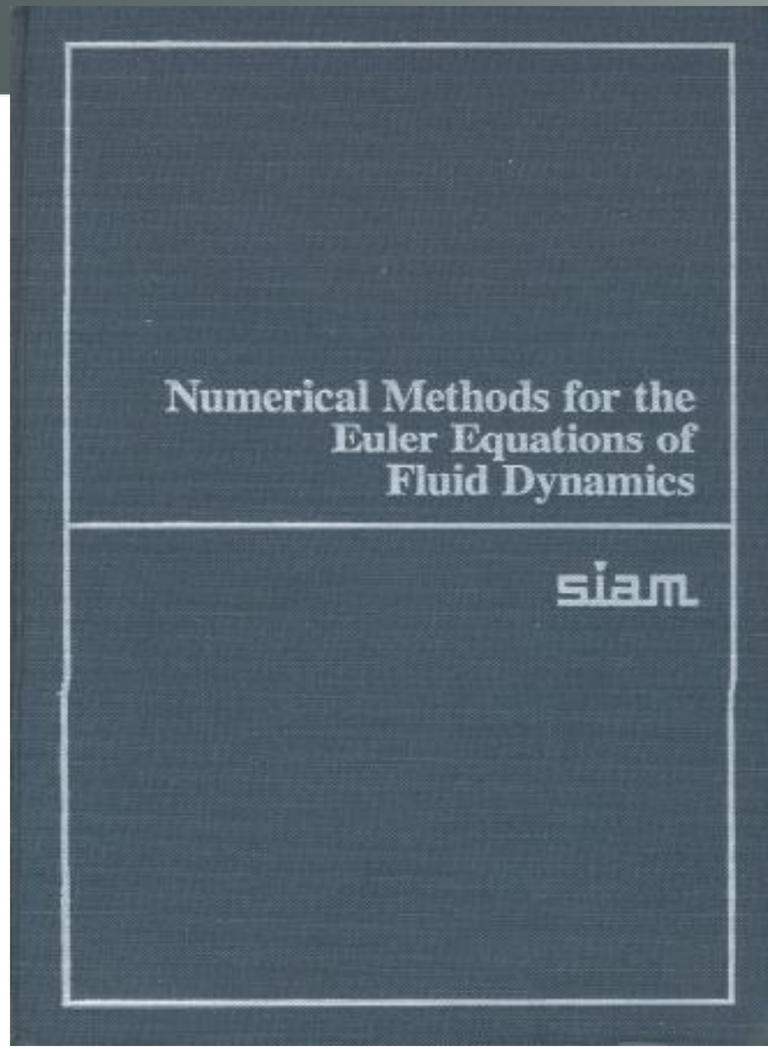
**10/04/2015**

HIGHER TOGETHER™

DASSAULT AVIATION

# My first participation to an international conference




INRIA Workshop
December 1983

# CFD Debates of last 30 years

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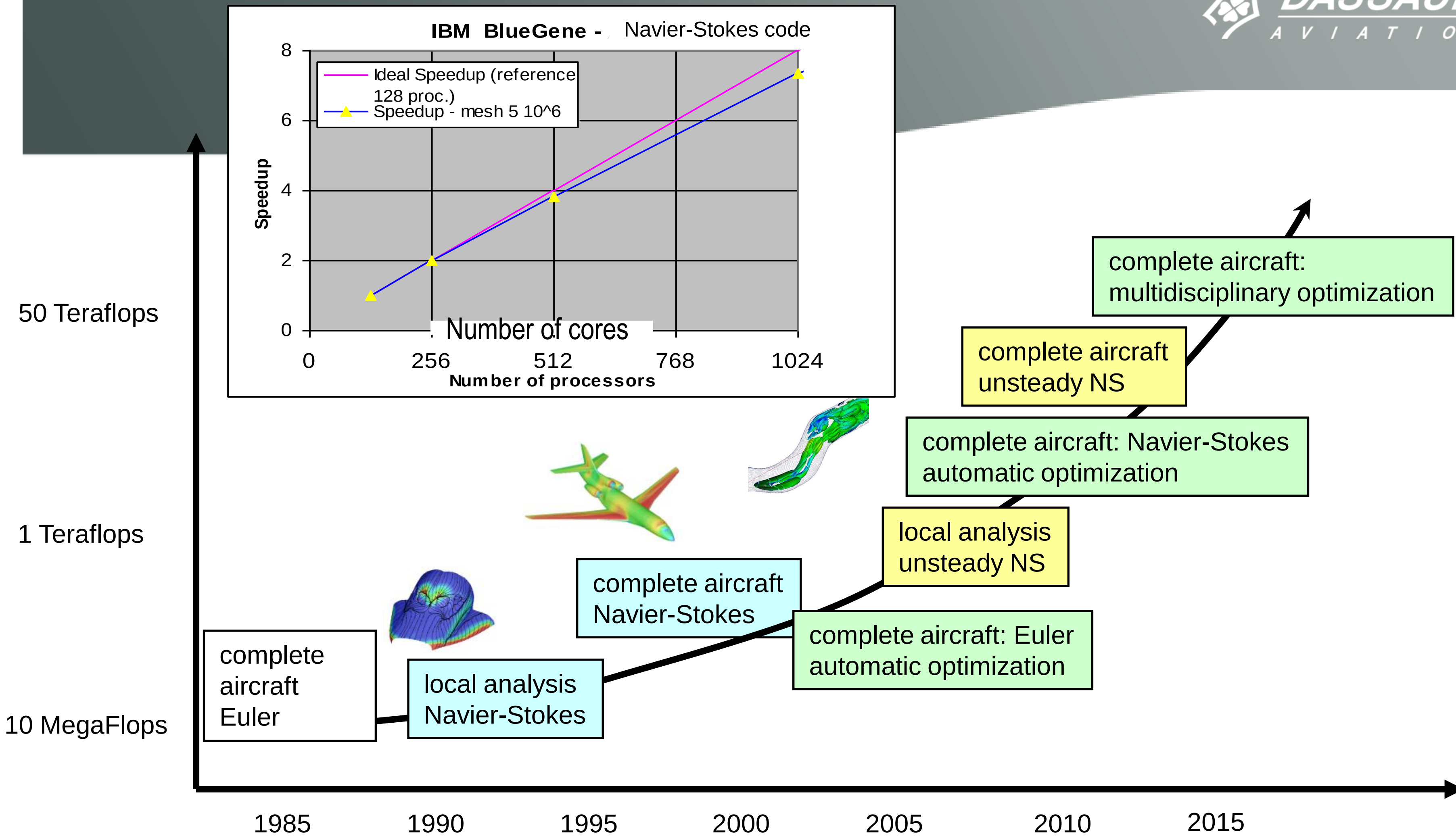
APPROXIMATION
- ❑ Centered vs upwind schemes
- ❑ TVD vs LED / positive schemes vs distributive schemes vs SUPG
- ❑ Structured vs unstructured meshes

SOLVING
- ❑ Multigrid vs implicit solving problems

OPTIMUM DESIGN
- ❑ Exact discrete vs continuous discretized adjoint equation
- ❑ Gradient-based vs evolutionary optimization techniques

# Computational capabilities over 30 years



# Early eighties

*A premiere: the first industrial complete aircraft aerodynamic computation*

- ❑ Falcon 50 aircraft
- ❑ Full potential equations
- ❑ Finite element discretization
- ❑ Least-square formulation

# Mid eighties: the emergence of Euler solvers

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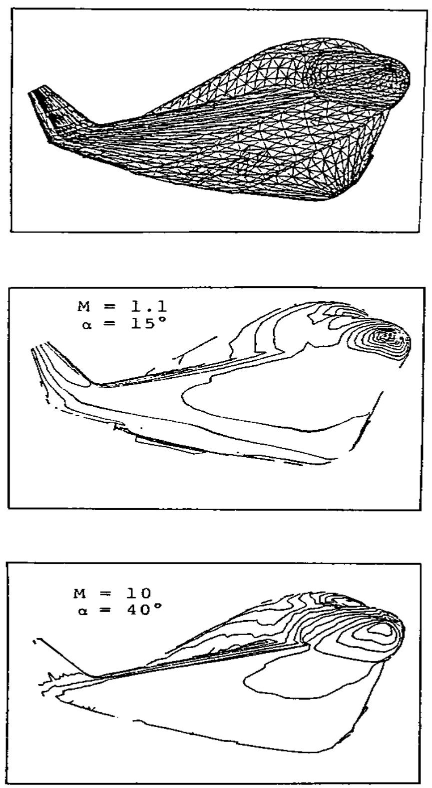
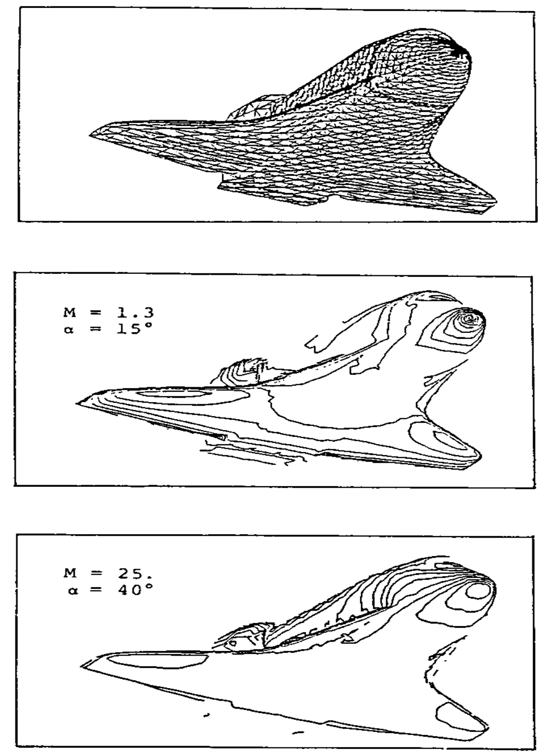



FIGURES 8 to 10

130




FIGURES 11 to 13

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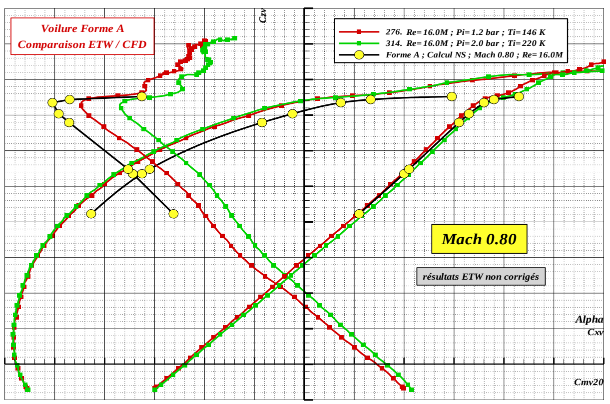
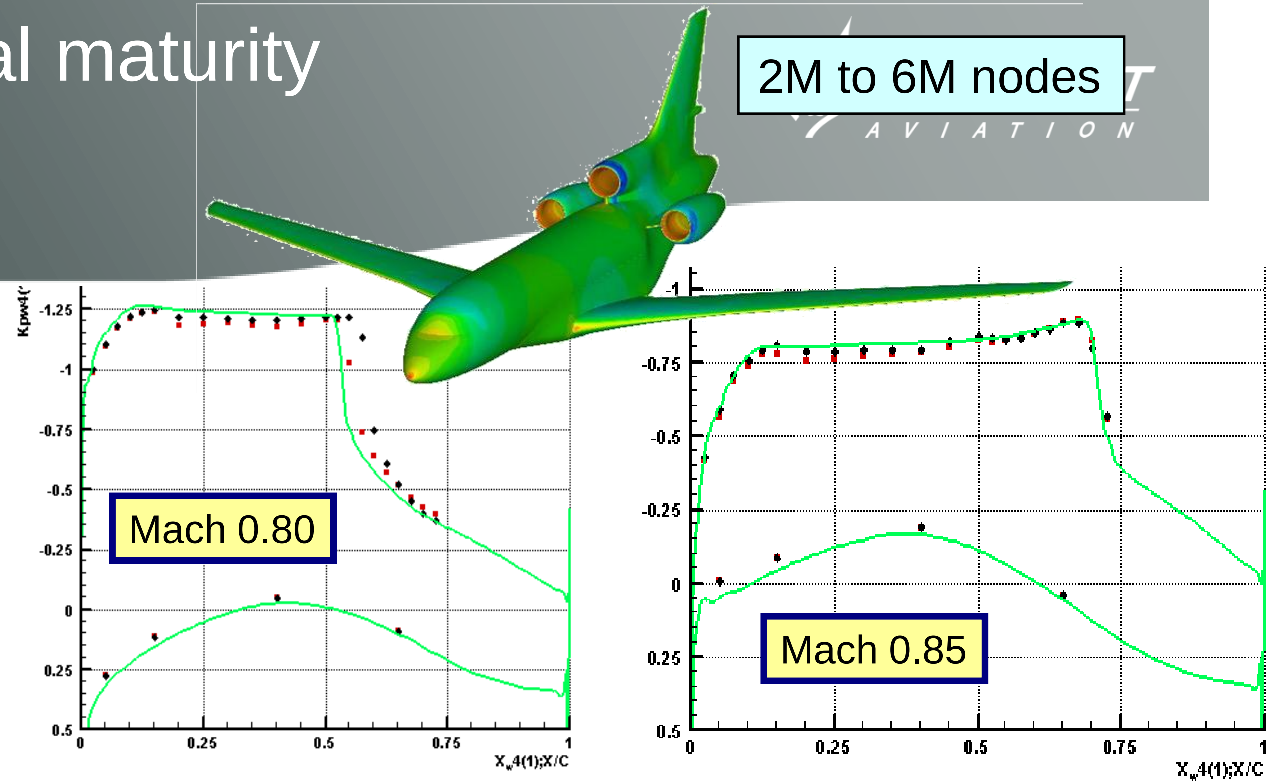
10 000 nodes
for a half geometry

# Mid 2000's: Industrial maturity of CFD codes

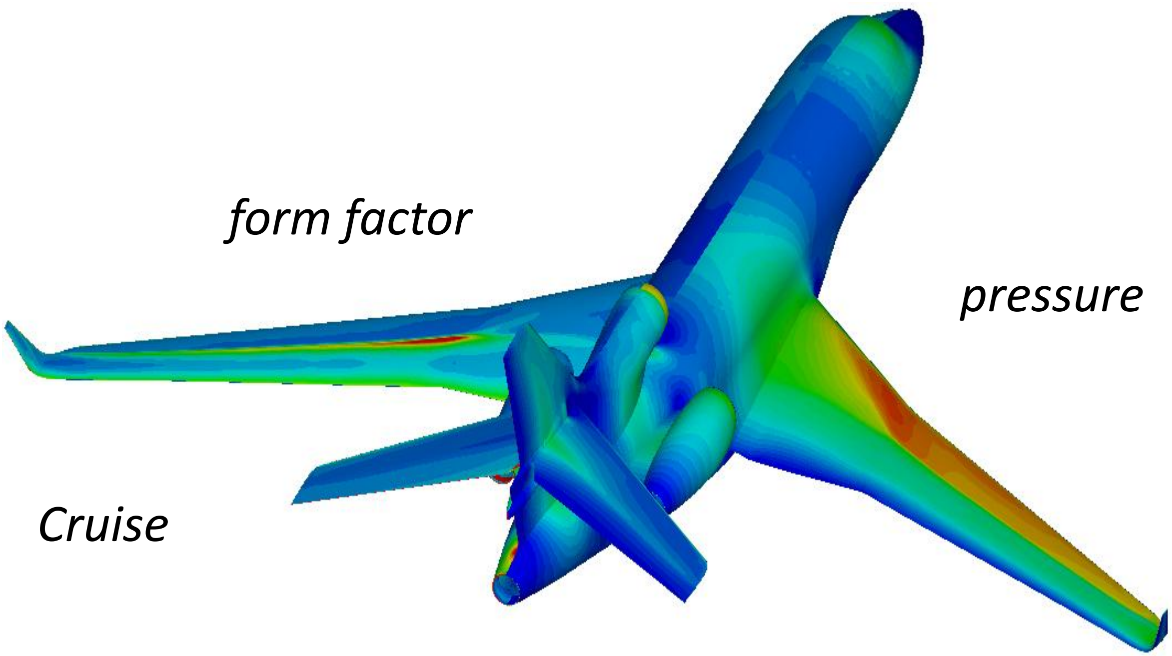
Cryotechnic test of generic Falcon shape in ETW




- Full aircraft Navier-Stokes simulations are used at all stages of design
  - Very good validation is obtained at cruise conditions
  - Design for cruise conditions is based on CFD
- Wind tunnel tests can be limited to intermediate and final check-out if sufficient validation is obtained at flight Reynolds number

# State of the art RANS
# Transonic cruise




**2001 – several hours**
**1 million grid points**

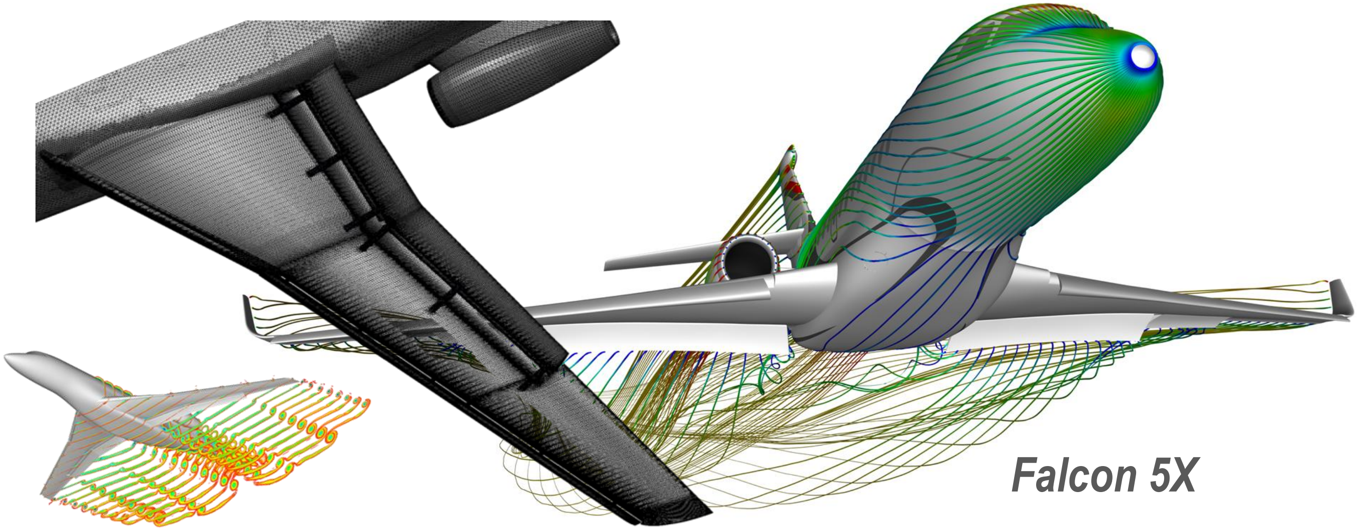
**2014 – 15 minutes**
**~20 million grid points**
**~500 computations possible per day**

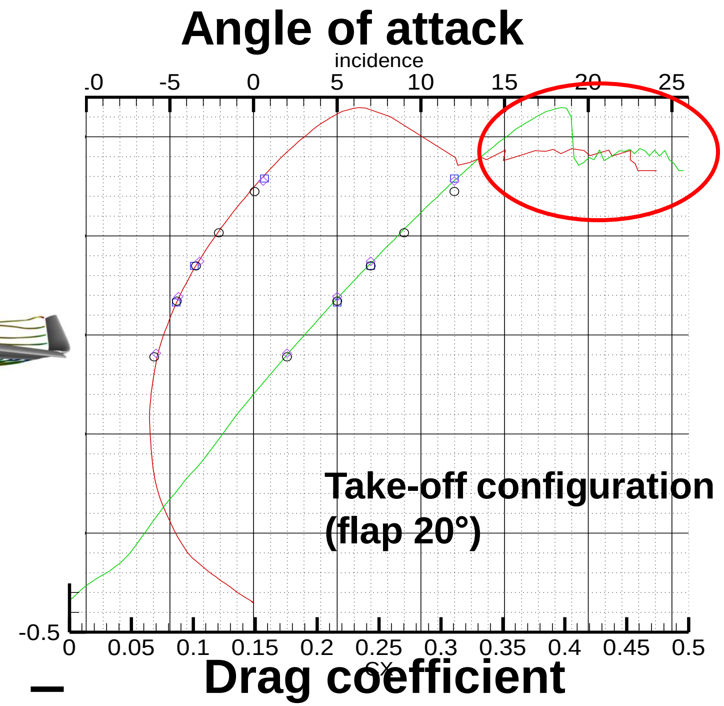
***→ challenge for the future :***

***- drag accuracy at cruise ~0.5-1% (viscous drag accuracy, corner flows, …) → improved RANS modeling***

***- 30 secs***

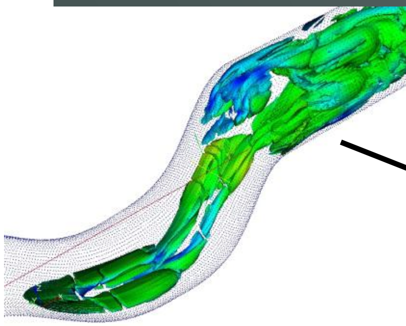
# Turbulence modeling
# State of the art RANS
# Take-off and landing

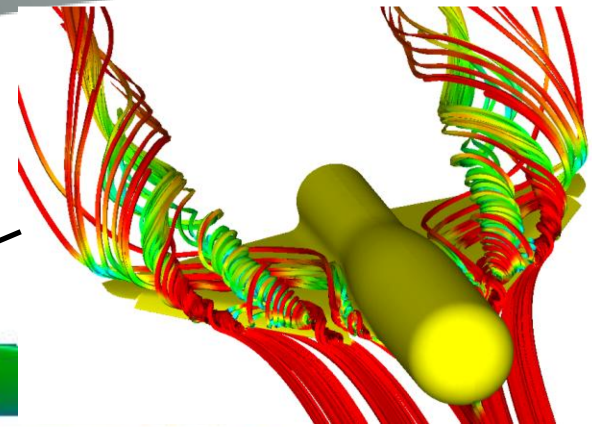


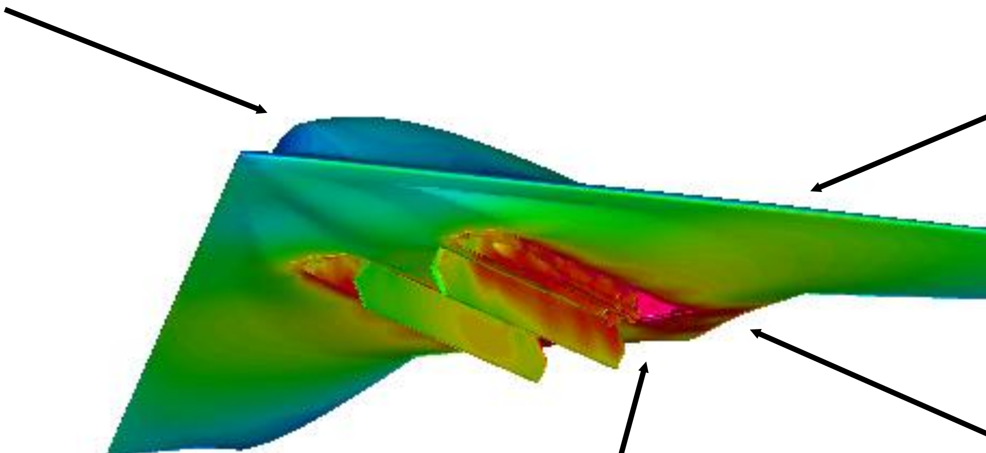



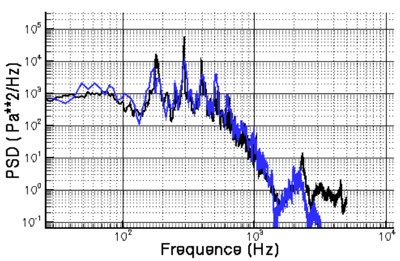

- ***WT is still the main design tool***
- ***CFD is not yet reliable enough predict max lift***
- ***CFD is a key tool for analysis and understanding of the local flow physics***
- ***Challenge for the future : accurate max lift (illustrate trend towards use of CFD for limits of flight domain)***
- ***→ improved RANS modeling***

# Turbulence modeling for complex flows

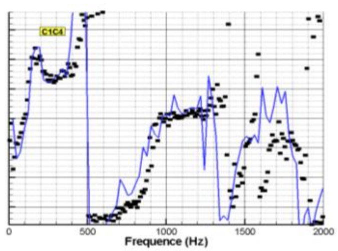




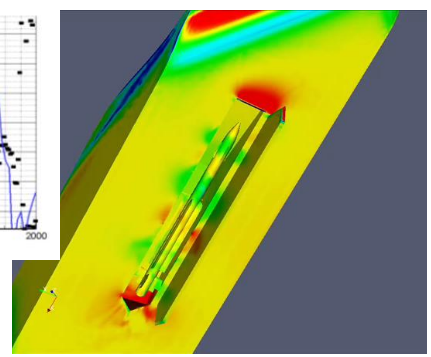


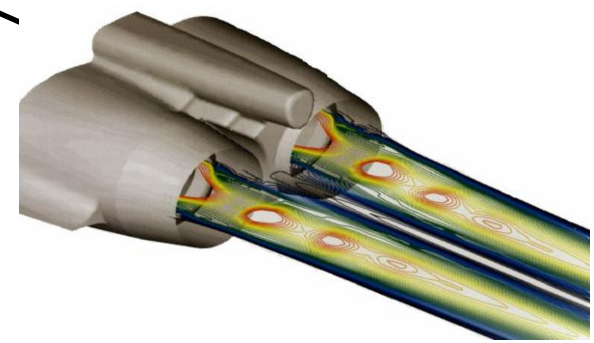



Autospectrum of unsteady pressure signal



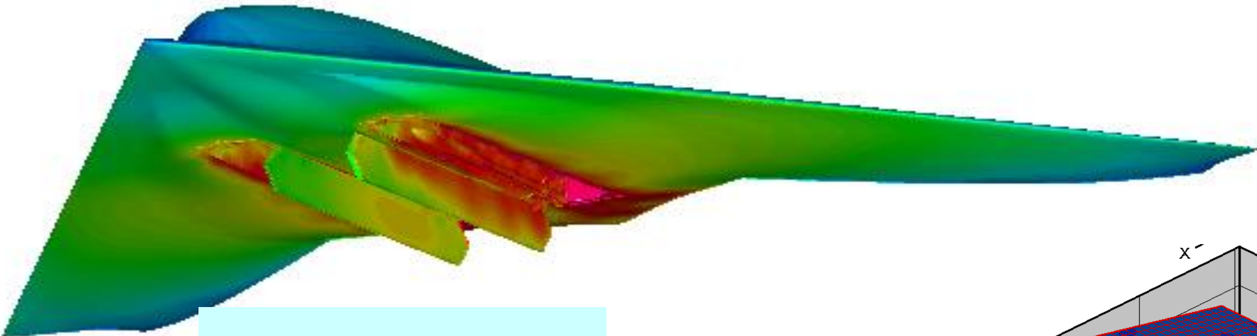

Correlation of unsteady pressure
Signals at two points



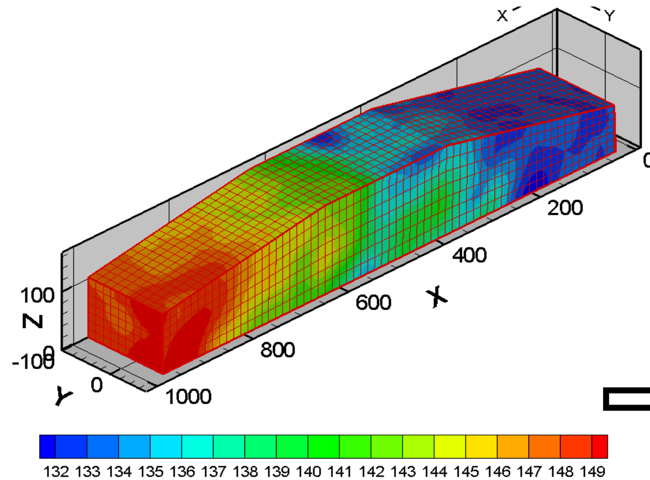


# Fatigue sizing of a structure

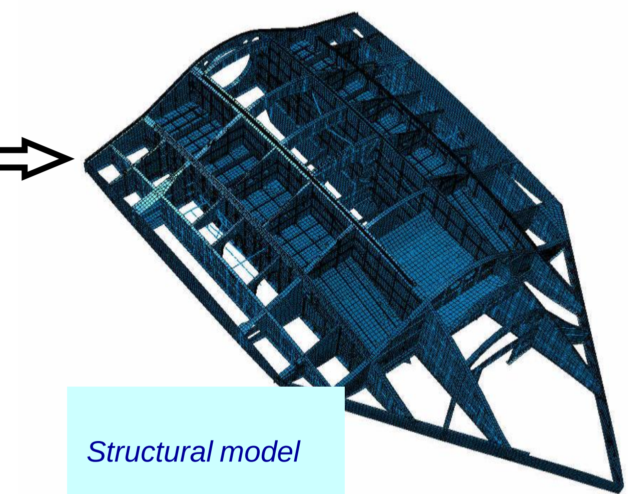
- Chargement de la structure par la base aéro-acoustique :
  - 1676  chargements en pression sur la soute (0-500 Hz)
  - Chaque chargement est corrélé avec tous les autres : matrice complexe 1676x1676 pour chaque fréquence



*Unsteady aerodynamic computation*

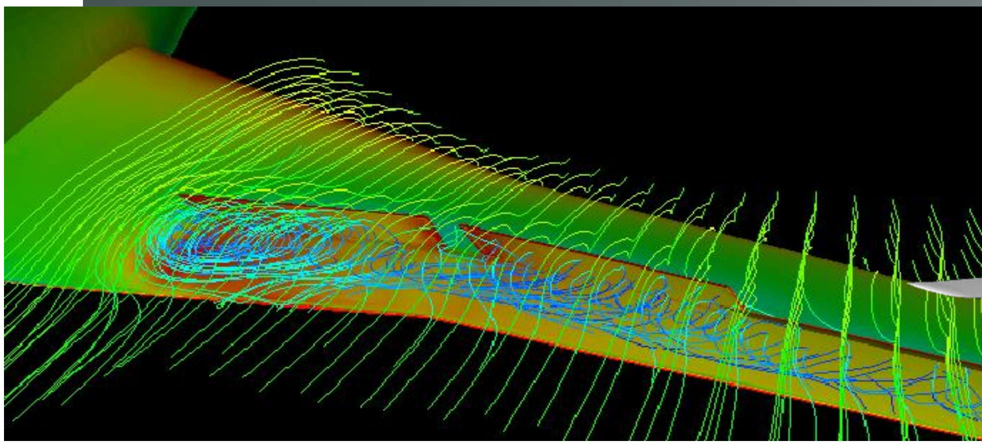


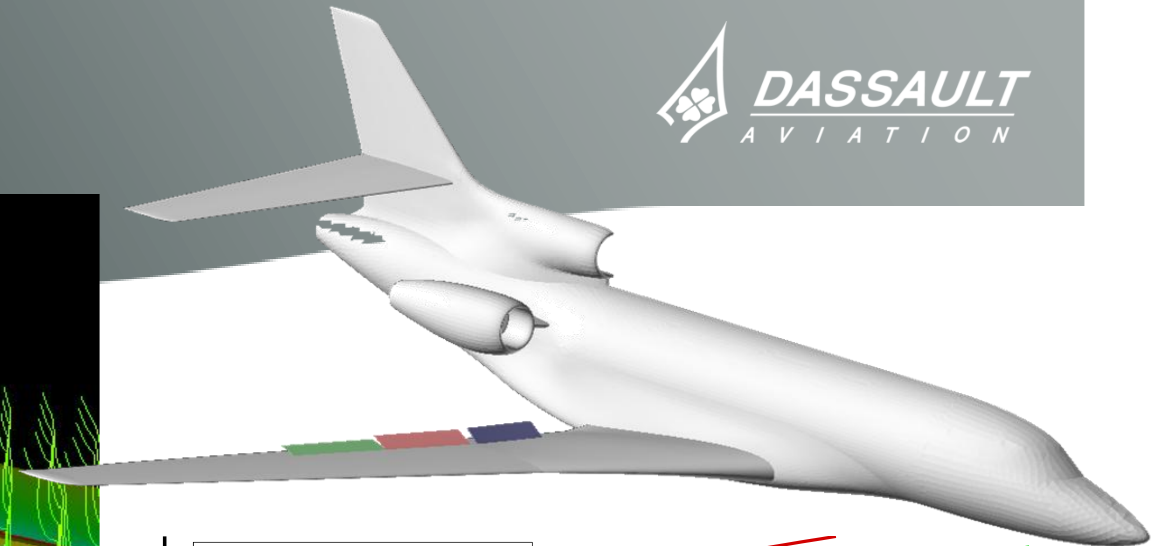

*Spectrum in dB (60 Hz) projected*

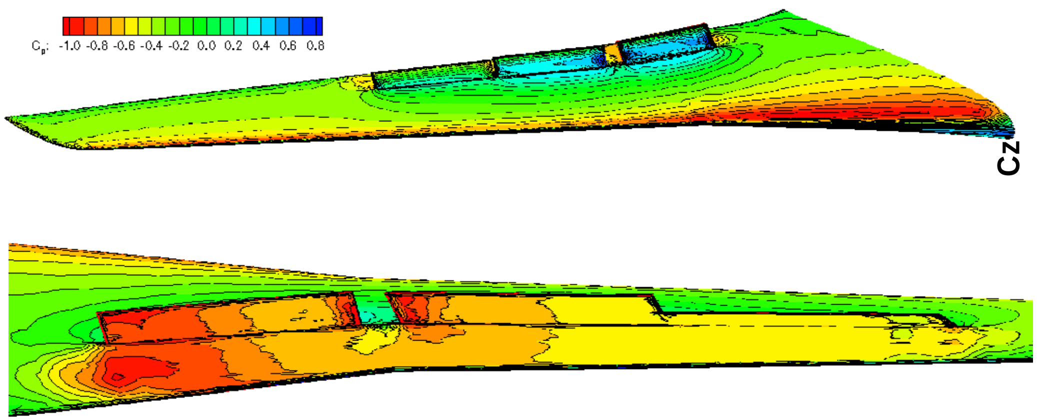


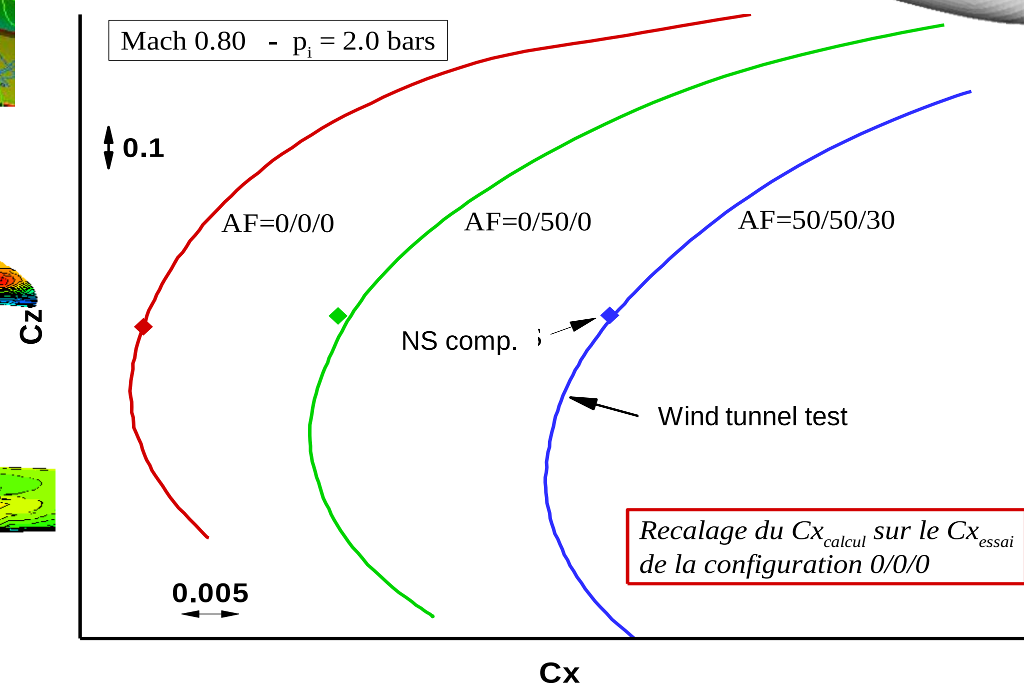
*Structural model*

# Airbrake design

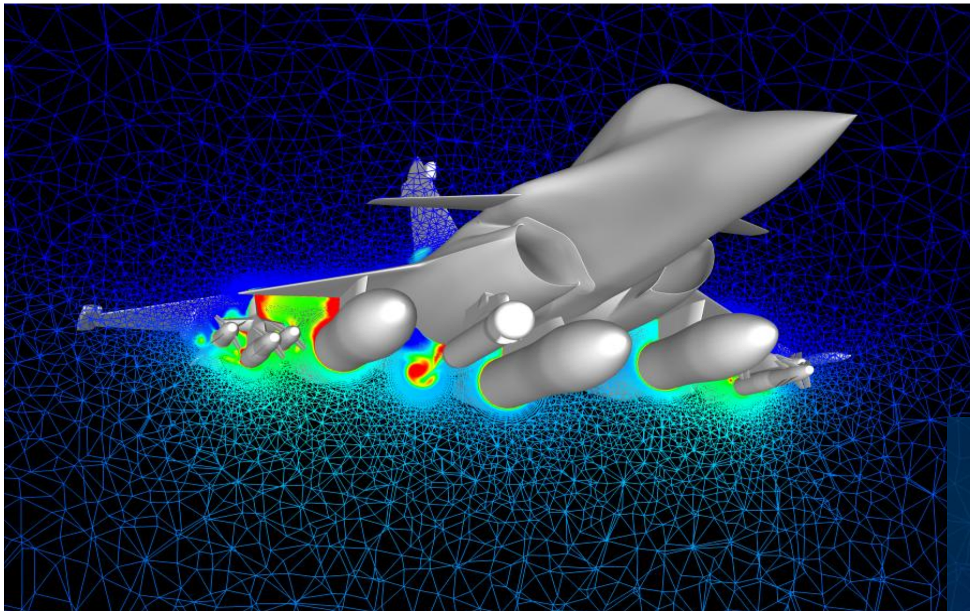




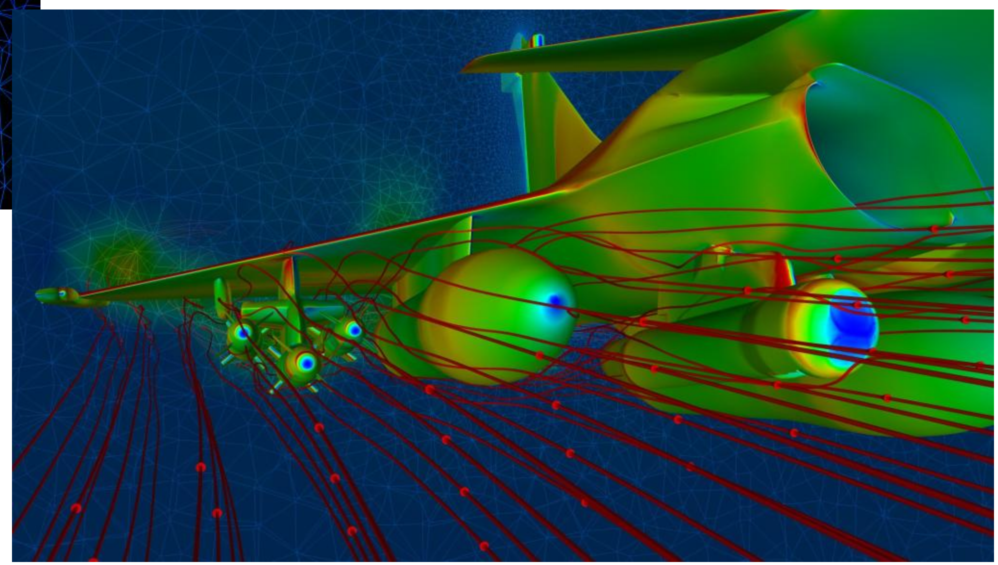


# Turbulence modeling
# State of the art RANS
# Weapon integration/separation



- ***Efficient process is required :***
  - ***many flight points***
  - ***many aircraft configuration (weapon mix on many attachment points)***
  - ***many store type (missile, bombs, tanks, pods)***
- ***Process combines CFD, Wind tunnel & flight***



# Computational trends

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Computers power will increase by a factor around 500 within the next 10 years:

1 week-long computation will be available in 1/2 hour

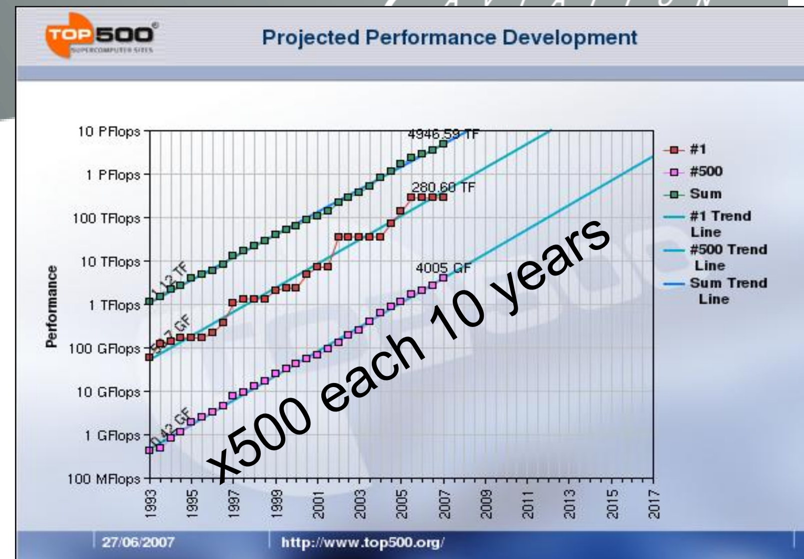
1day-long computation will be available for automatic optimization

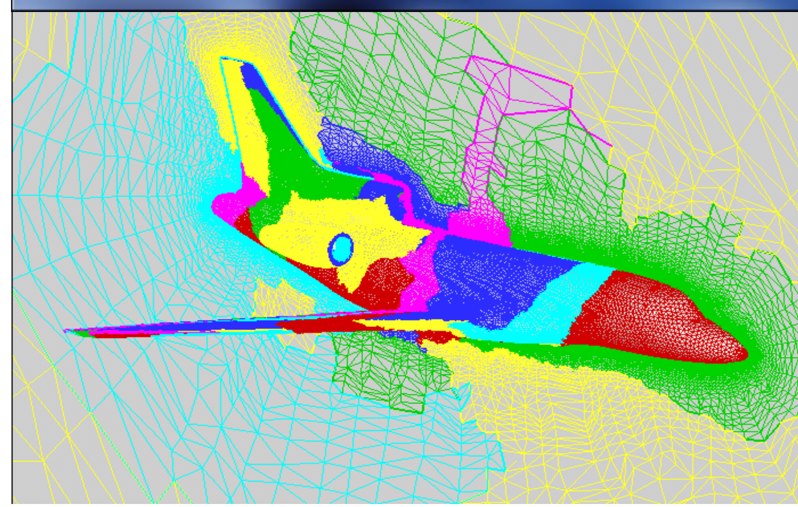
1 hour-long computation will be available interactively

Open the way for short cycle Multi-disciplinary Design Loop

Computers architecture evolves to an almost exponentialy increasing number of processors

The architecture of the Codes must fit to the computers' one



# Contribution of numerical simulation

## Design iterations based on a virtual product

Cost reduction

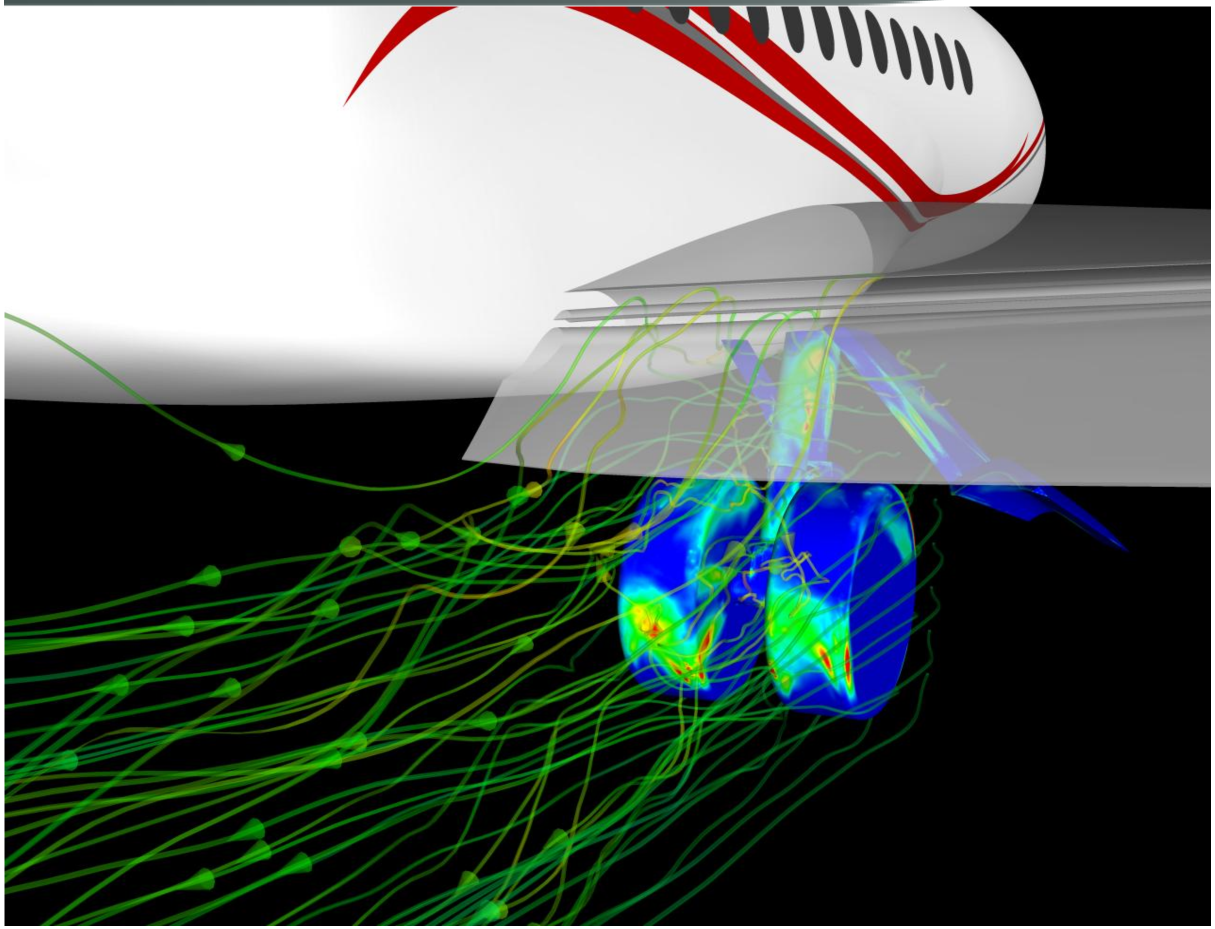
## Optimization and trade-off

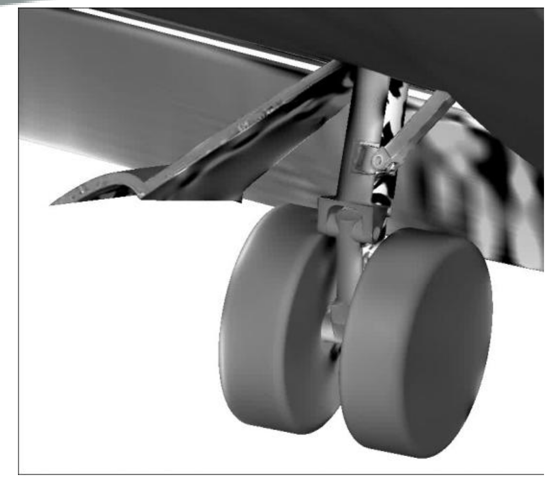
Evolving requirements

## Risk mitigation before flight

Performances prediction

# DES application to airframe aeroacoustics
# Landing gear noise





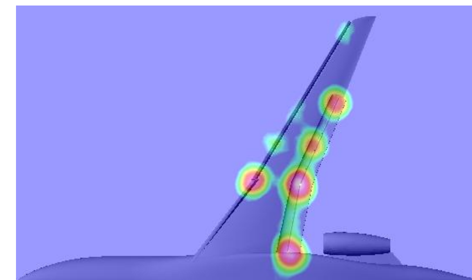


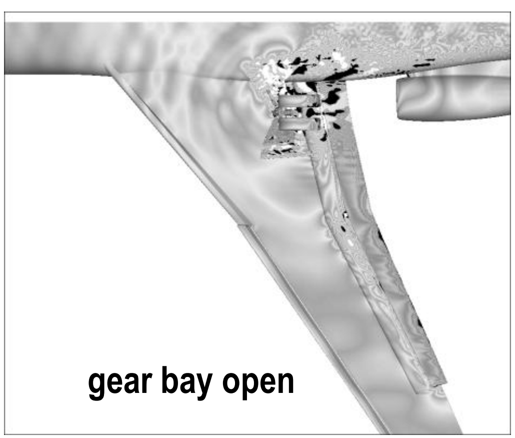
**15 days on 2048 BG/P cores**

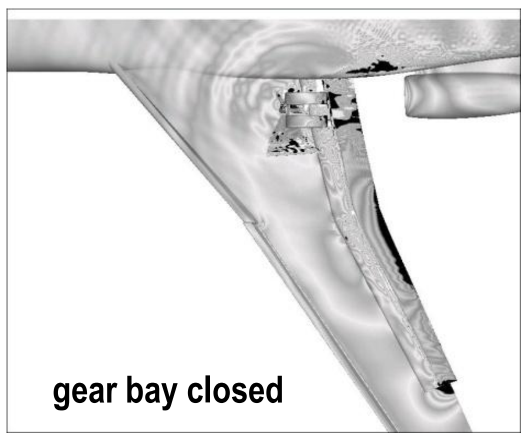
# DES application to airframe aeroacoustics
# Landing gear noise
# Influence of landing gear bay

## Example of detailed study: gear bay integration

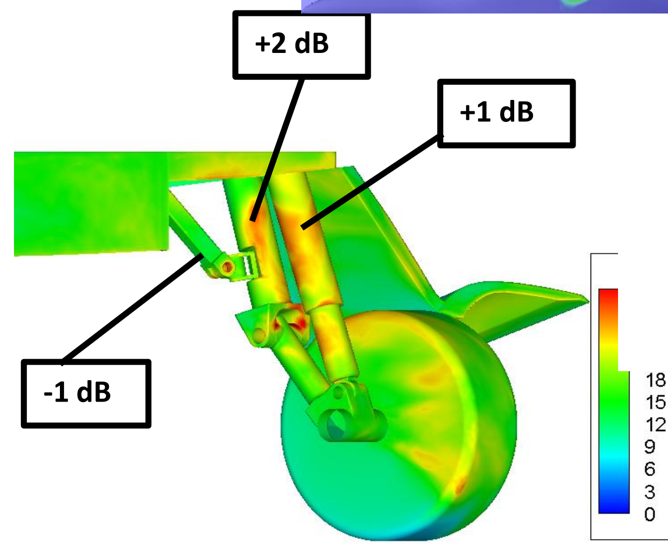
- Gear bay as a noise source
- Disturbance of mean flow field due to gear bay
- Mixing layer over the bay interacting with gear components





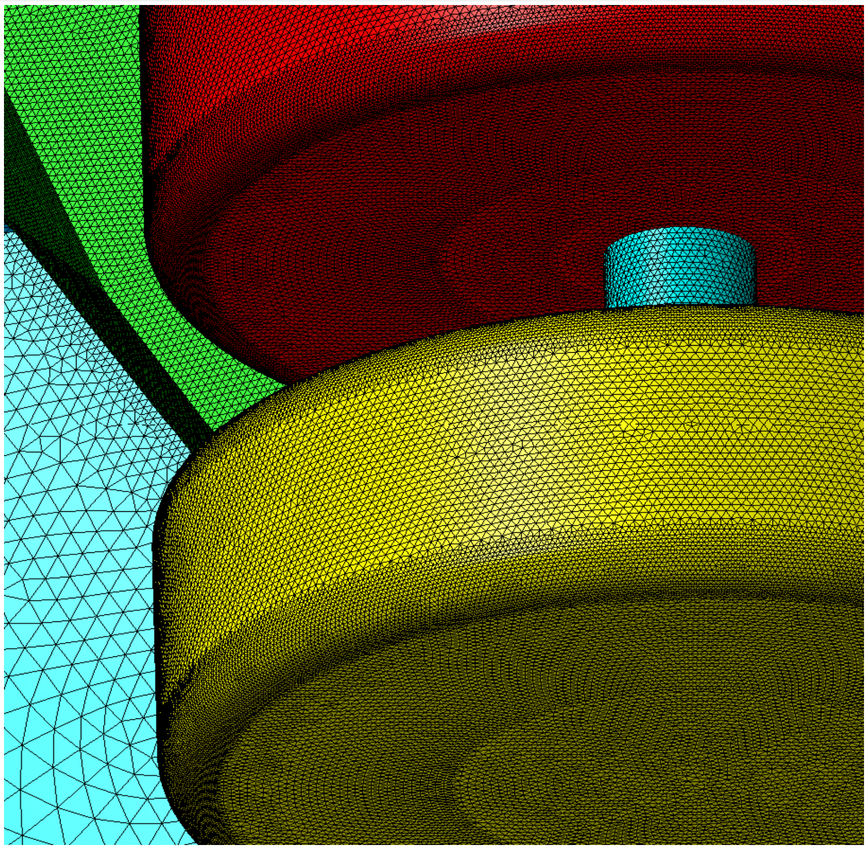




Acoustic pressure (bottom view of the aircraft)

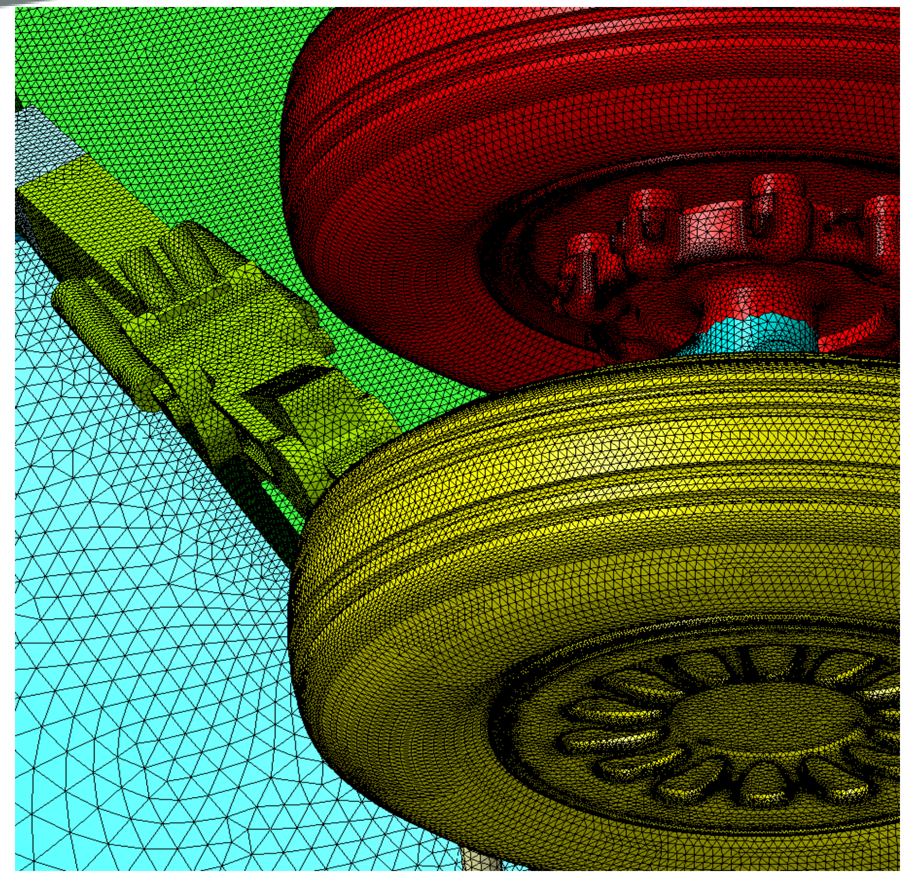



Modification of noise sources intensity due to gear bay opening

# DES application to airframe aeroacoustics
# Landing gear noise
# Influence of geometrical details

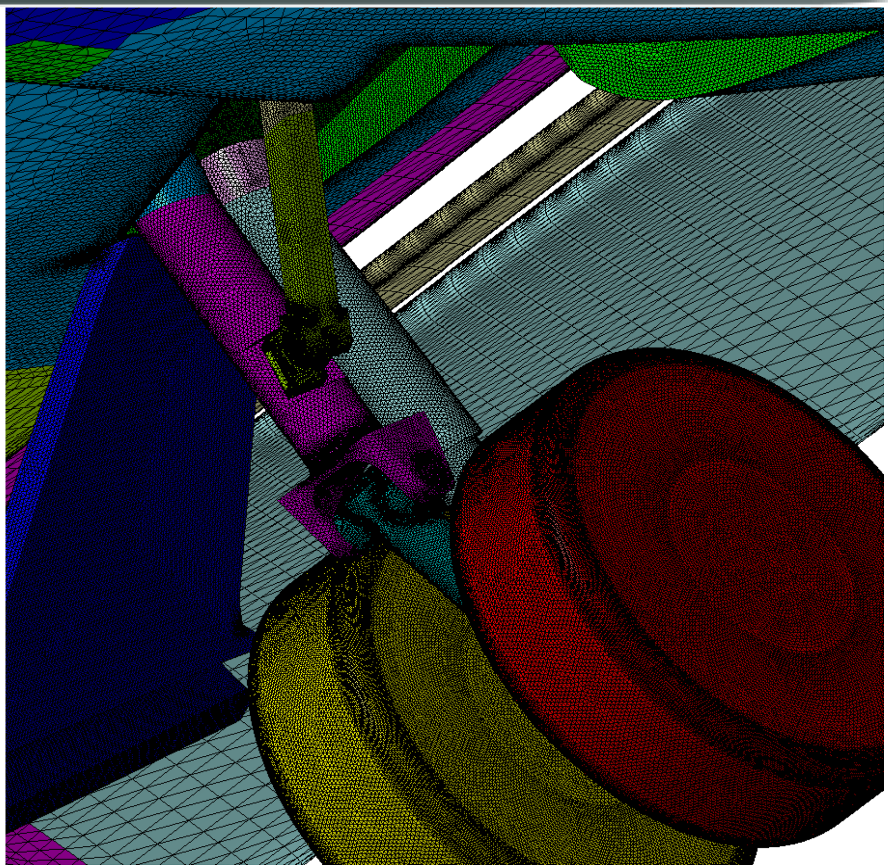


**Surface mesh – « simplified » landing gear**
**430 809 nodes**



**Surface mesh – « complex » landing gear**
**493 445 noeuds**

# DES application to airframe aeroacoustics
# Landing gear noise
# Influence of geometrical details



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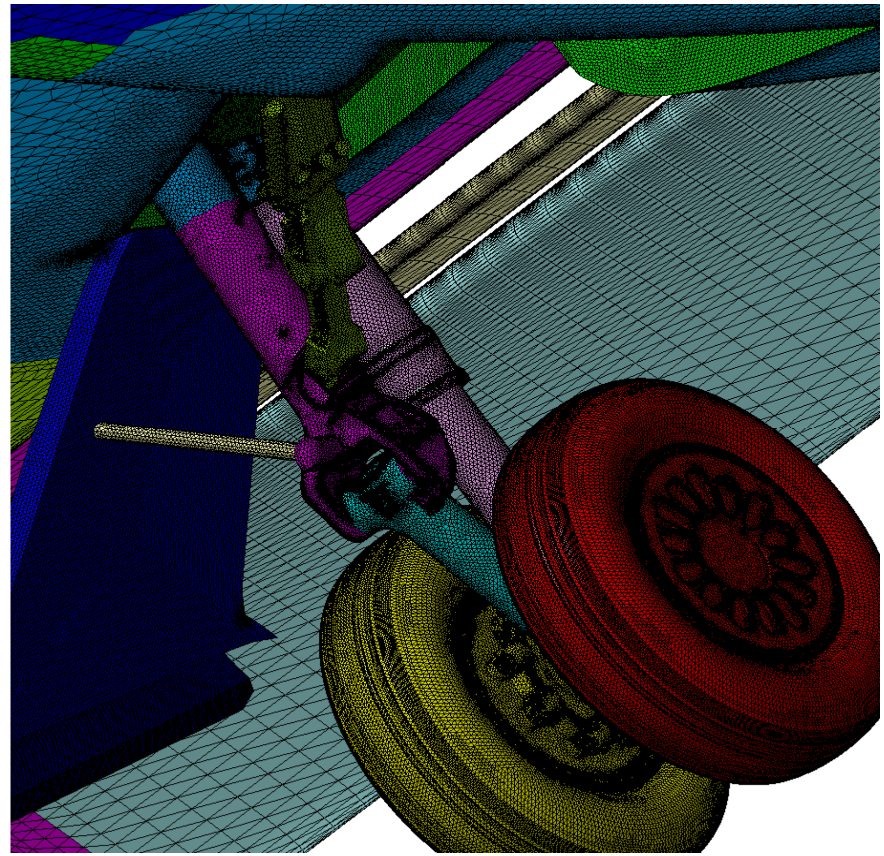

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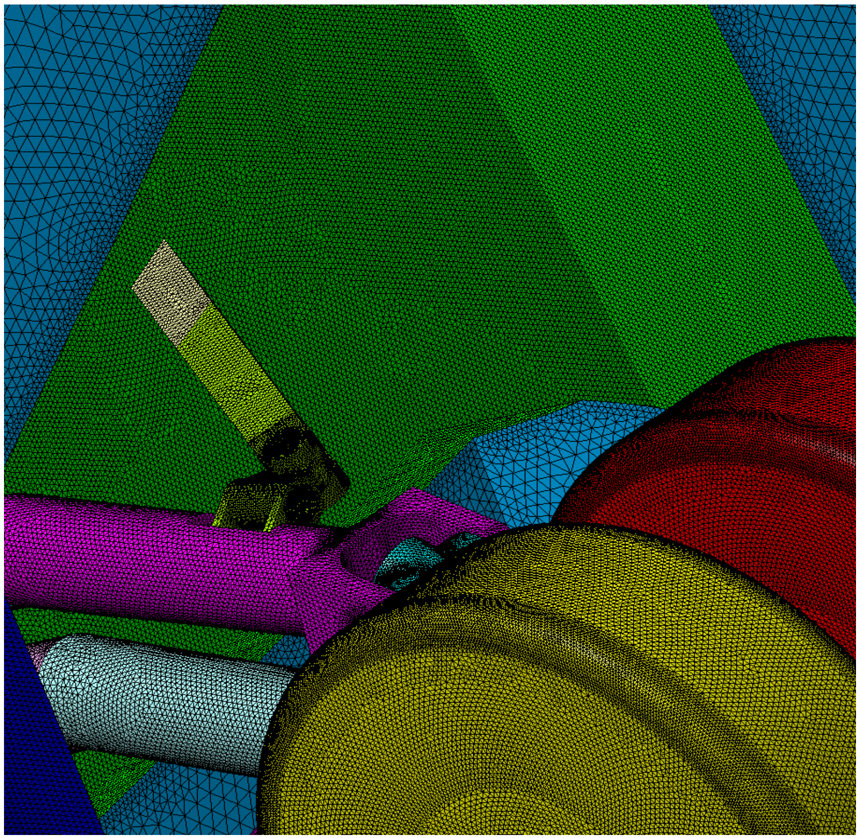
# Application to airframe aeroacoustics
# Landing gear noise
# Influence of geometrical details



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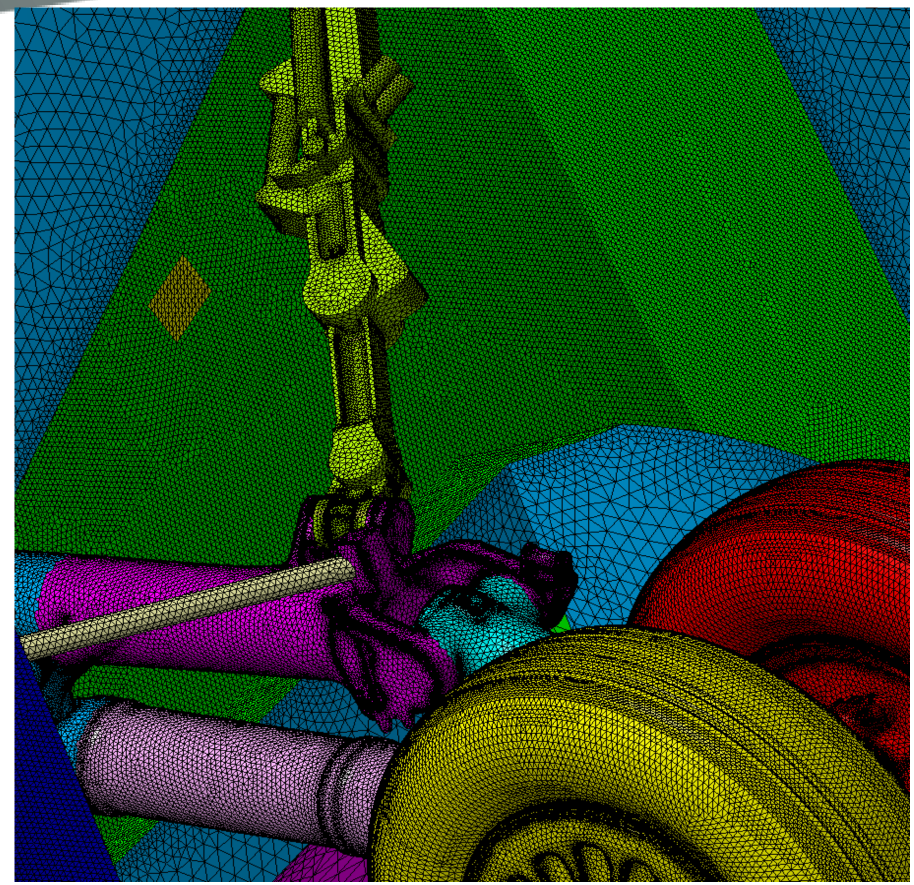

**Surface mesh – « complex » landing gear**
**493 445 noeuds**

# Application to airframe aeroacoustics
# Landing gear noise
# Influence of geometrical details

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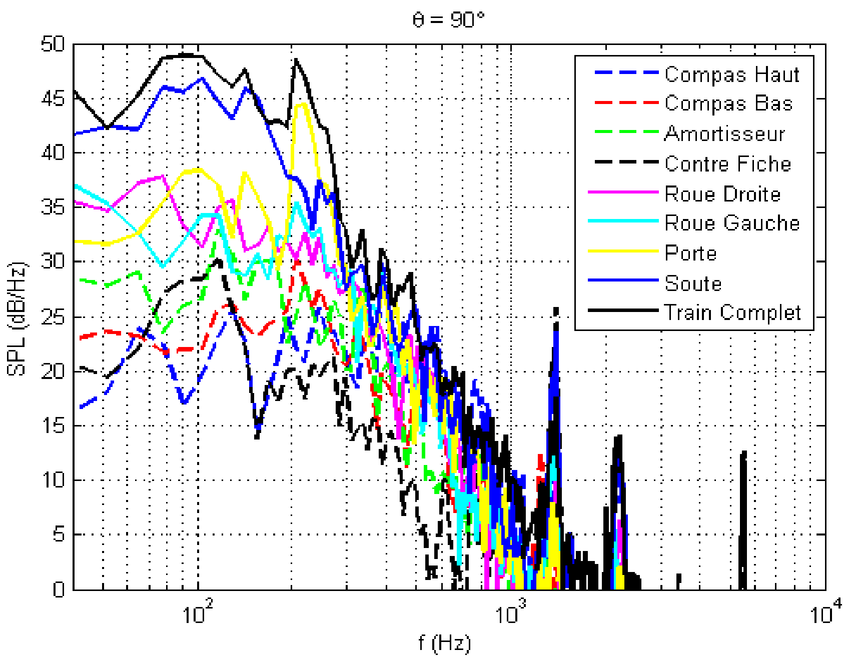
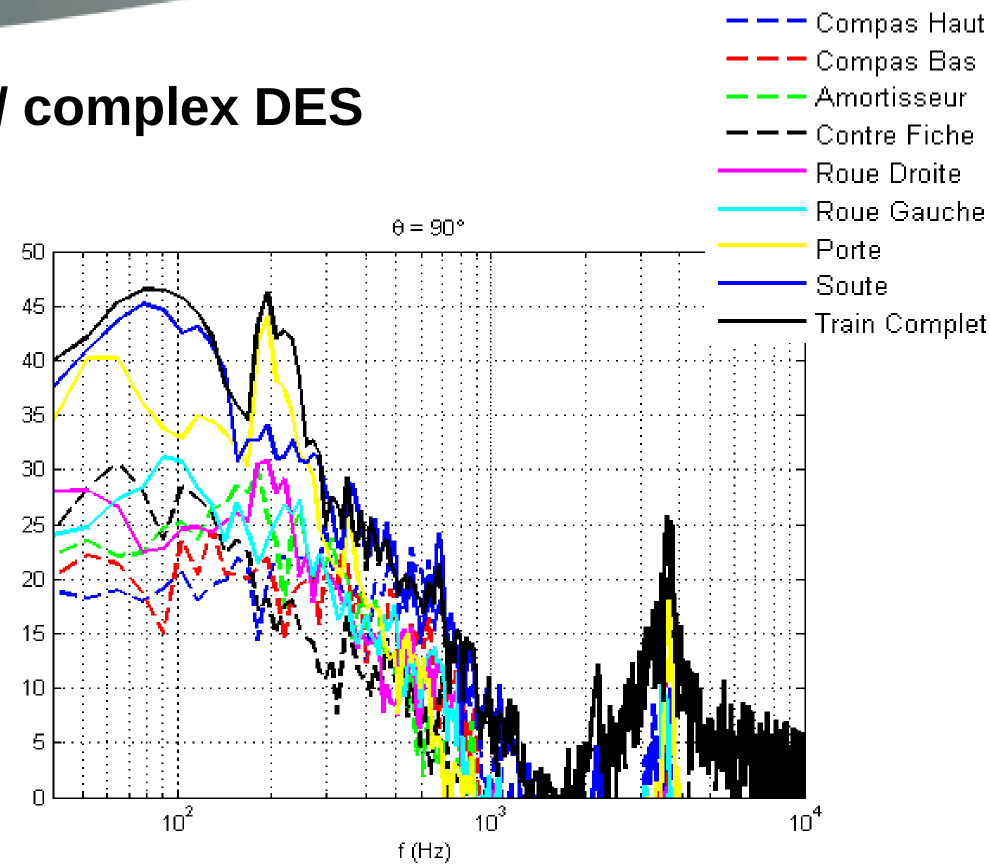
## Far field spectra – simple / complex DES




SPL (dB/Hz)
Simple landing gear / Experiment




SPL (dB/Hz)
Complex landing gear / Experiment