Presented by

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Loads & Aeroelastics
Airbus Operations

Aeroelasticity in Aircraft Development: Challenges and Objectives

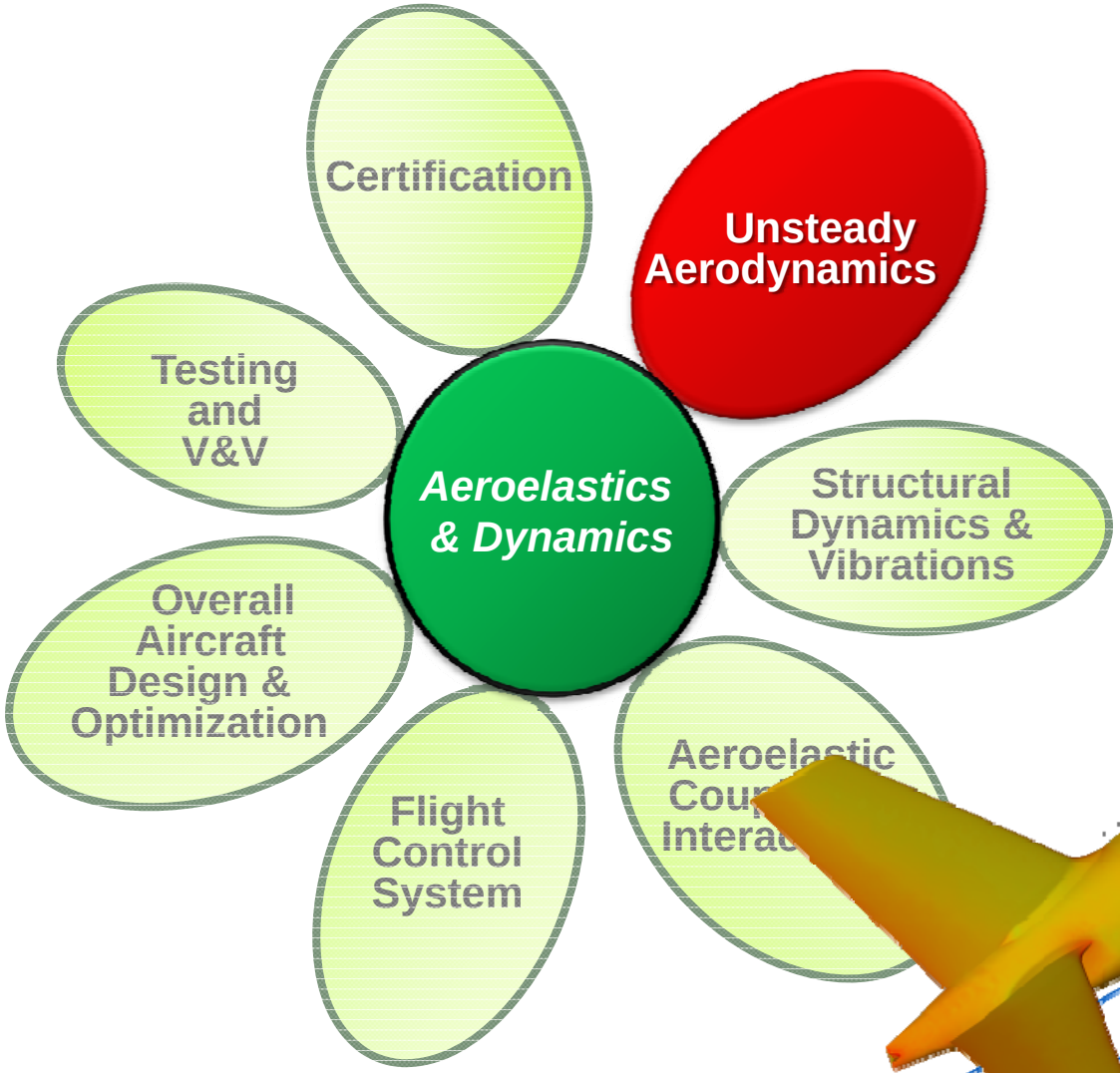
Aeroelastics Workshop Liverpool University, 13-15 Sep 2010

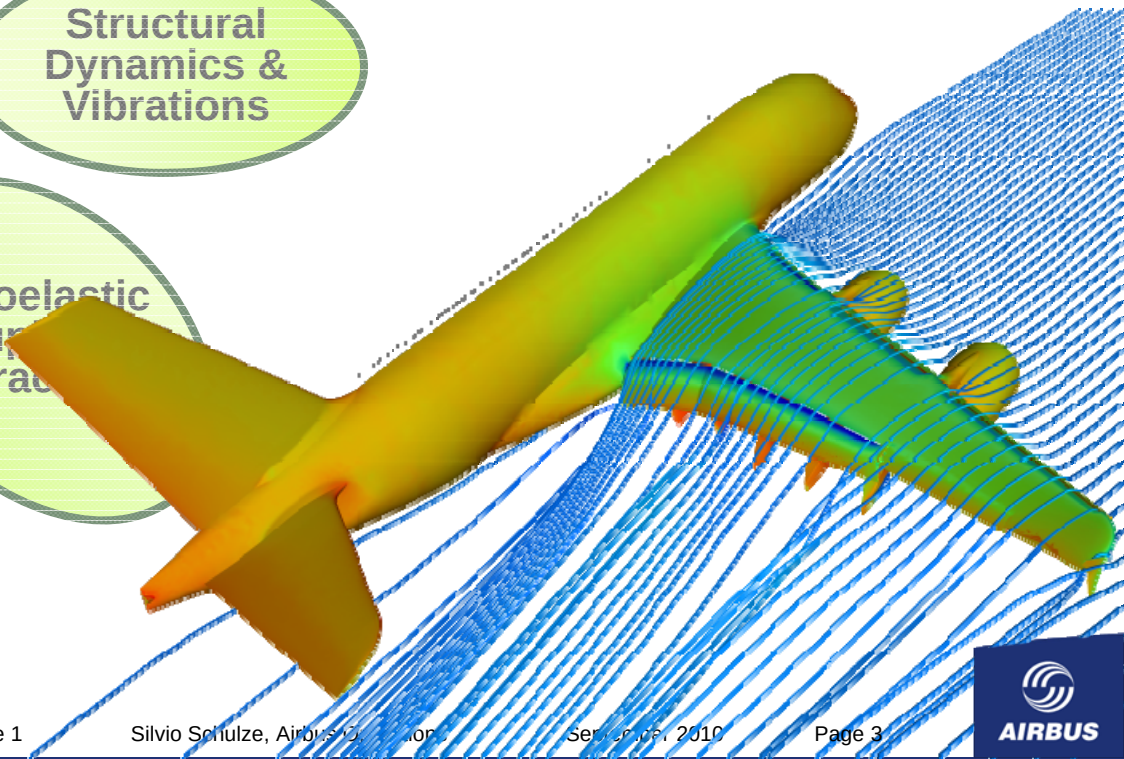
Aeroelastics Core Activities / Processes

Business Drivers

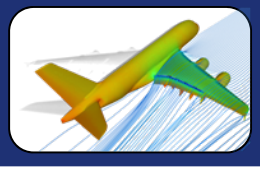
- Product Policy
- New Technology
- Time to Market

Aeroelastics Core Activities / Processes





Unsteady Aerodynamics

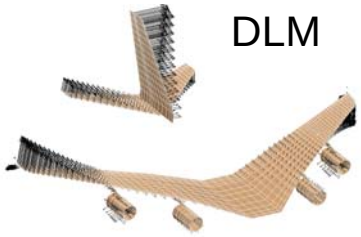


Process & Evolution

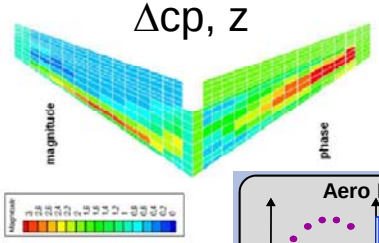
Baseline | **Correction** | **Direct CFD**

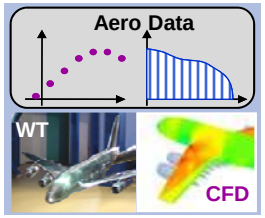
Today

DLM

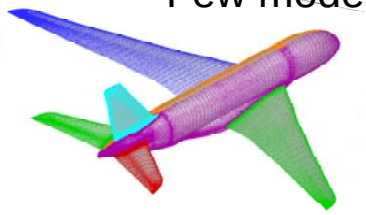


Δcp, z



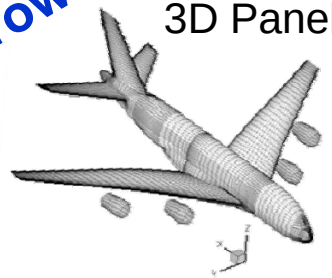


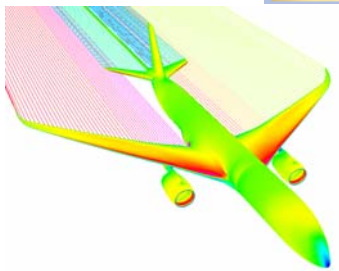
Few modes



Tomorrow

3D Panel

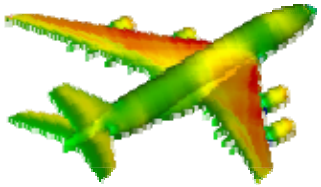




Cp u/l

x,y,z

- All modes
- Complex geometry



Geometric Detail | **Correction Capability** | **Aerodynamic Detail**

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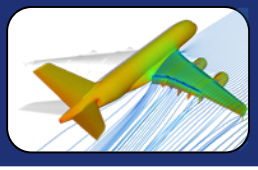
Unsteady Aerodynamics

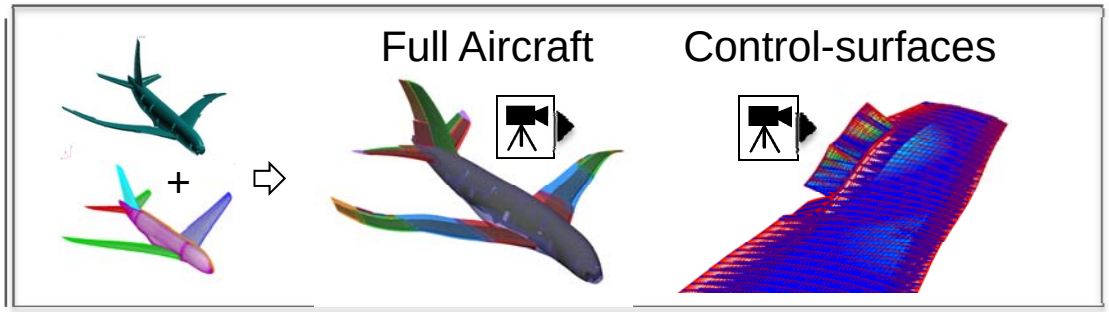


CFD for Aeroelastics

Challenges

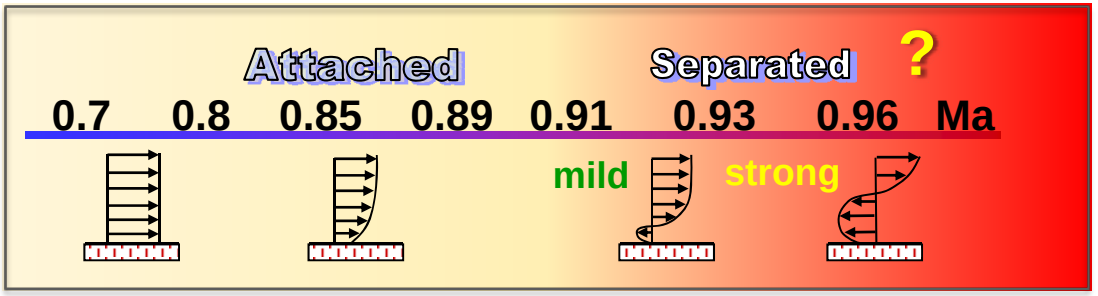
Capability

- Full Mode Shape Capability
  - Robust Moving Mesh
  - Chimera



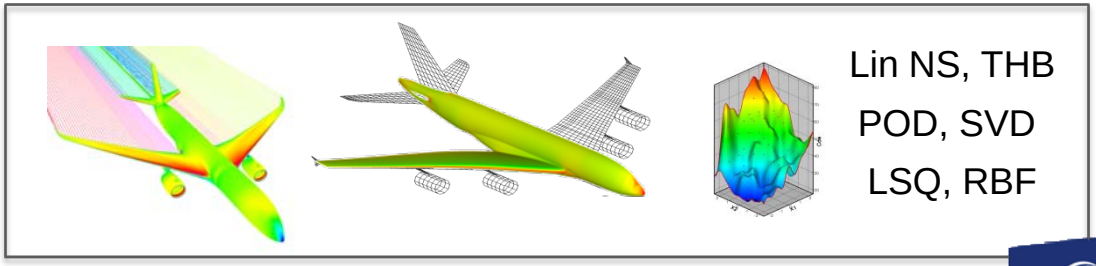
Accuracy

- Full Flight Envelope
- High Cl, Ma, α
- Control-surface/Spoilers



Efficiency

- Rapid CFD
- Variable Fidelity
- ROM, Approximation



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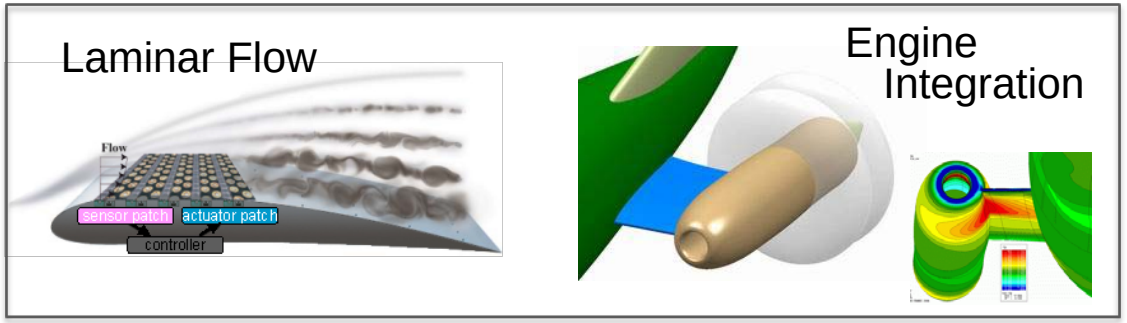
Unsteady Aerodynamics

CFD for Aeroelastics

Challenges, cont.

Future Designs

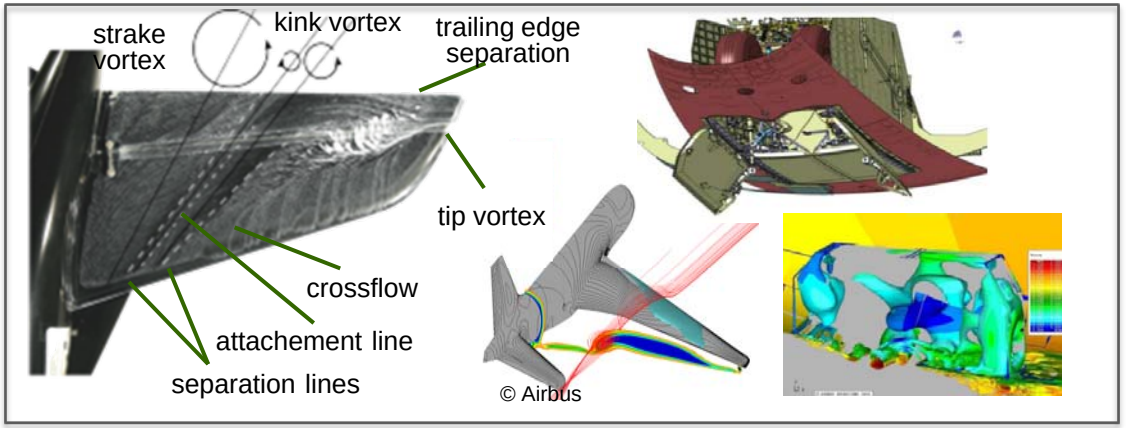
- Passive/Active Flow Control
- Future Propulsion Systems



Detached Flows

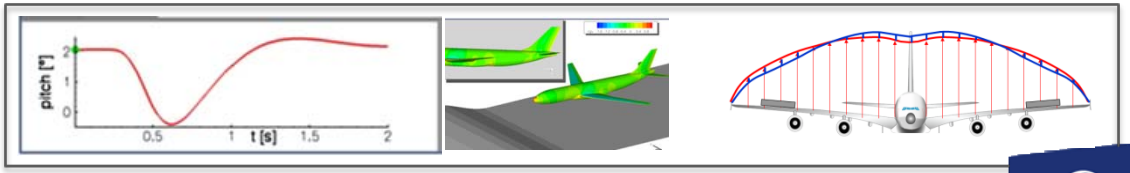
- Wakes, Jet Effects, Cavities

in support of Landing Gear Doors/Fairings/Flaps design



Future Applications

- Aircraft Gust Response
- Aircraft Rational Manouvre



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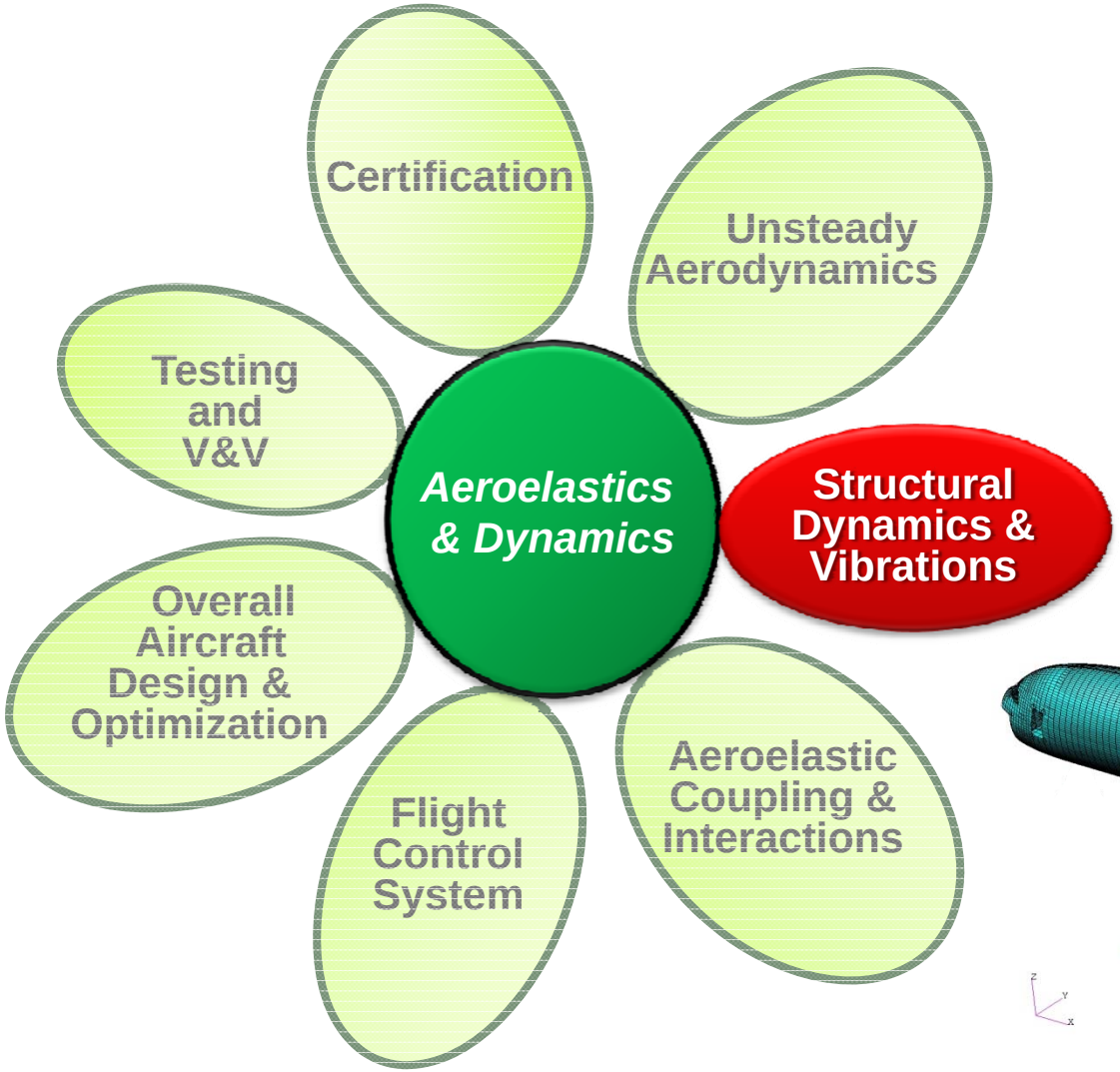
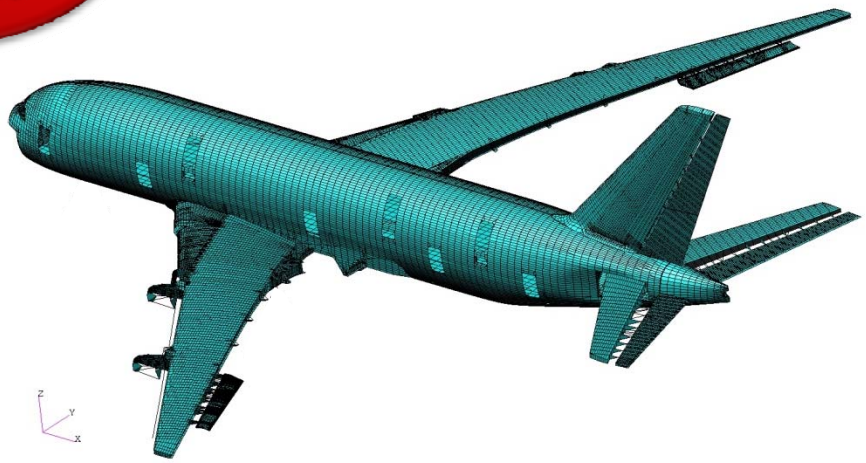
Aeroelastics Core Activities / Processes





Improvement Objectives & Challenges

Major Component Interfaces	**Propulsion System Integration**	**Control Surfaces Integration**
Damping Prediction	**High-Lift Integration**	**Landing Gear Integration**
Hydro-Elastic Vibrations	**APU Integration**	**…**

Structural Dynamics & Vibrations

Improved Interface Modeling

Major Component Interfaces

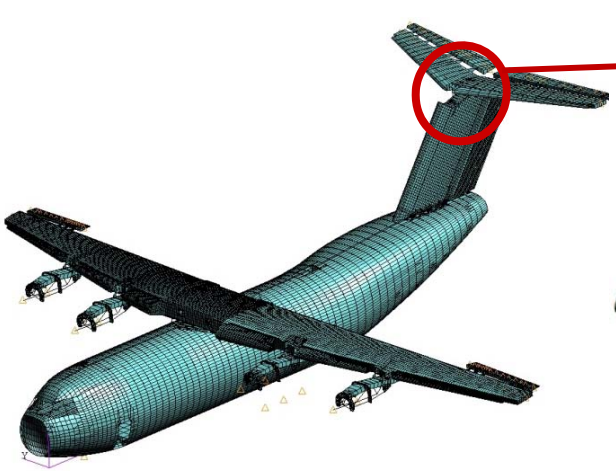
Challenge

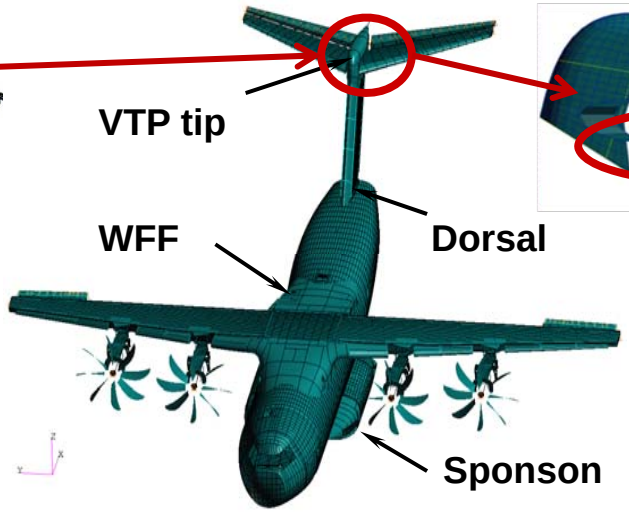
- How to represent secondary structure effects in the Dynamic Master Model with regard to global/local stiffness participation / damping / non-linearity ?

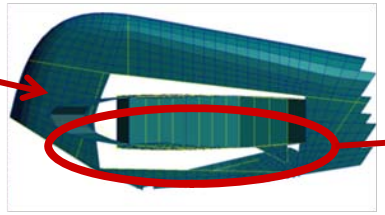
Dynamic Master Model (primary structures)

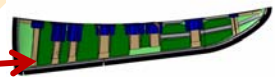
Detailed FEM (primary & secondary)

Detailed FEM (incl. local structures)









Cover Shield

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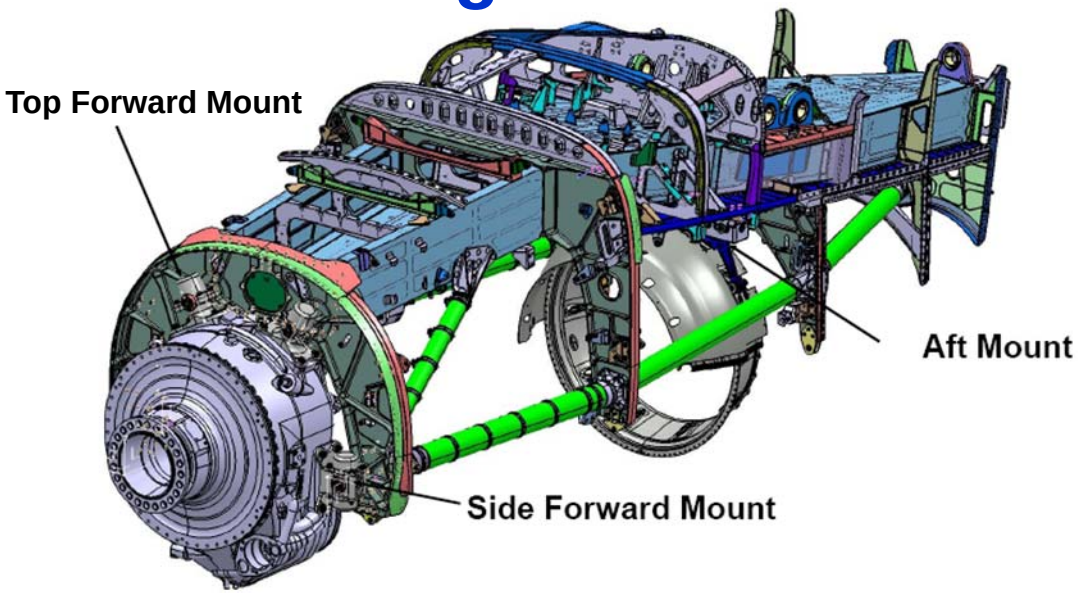
Structural Dynamics & Vibrations

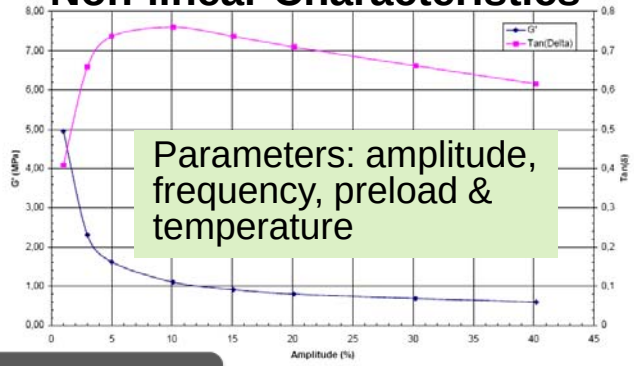
Propulsion System Integration

Local Non-linearities Treatment

Soft Mounted Engines



Non-linear Characteristics



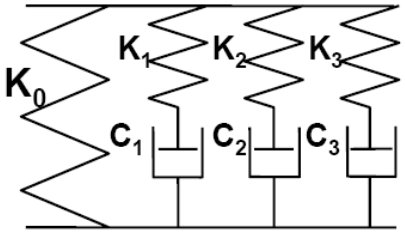
Parameters: amplitude, frequency, preload & temperature

Challenge

Improved Modeling in line with Needs & Process

Applications	Non-linear Effects	DMM Integration
• Whirl, low freq. • Engine induced vibrations, mid freq. • SEI, high freq.	• Stiffness/damping as function of oscillatory amplitude & frequency	• Simplified model • Use of classical liner elements

Maxwell model:



'Prony series'

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Structural Dynamics & Vibrations

Control Surfaces Integration

Actuator/Aero Non-linearities

Actuator Non-lin

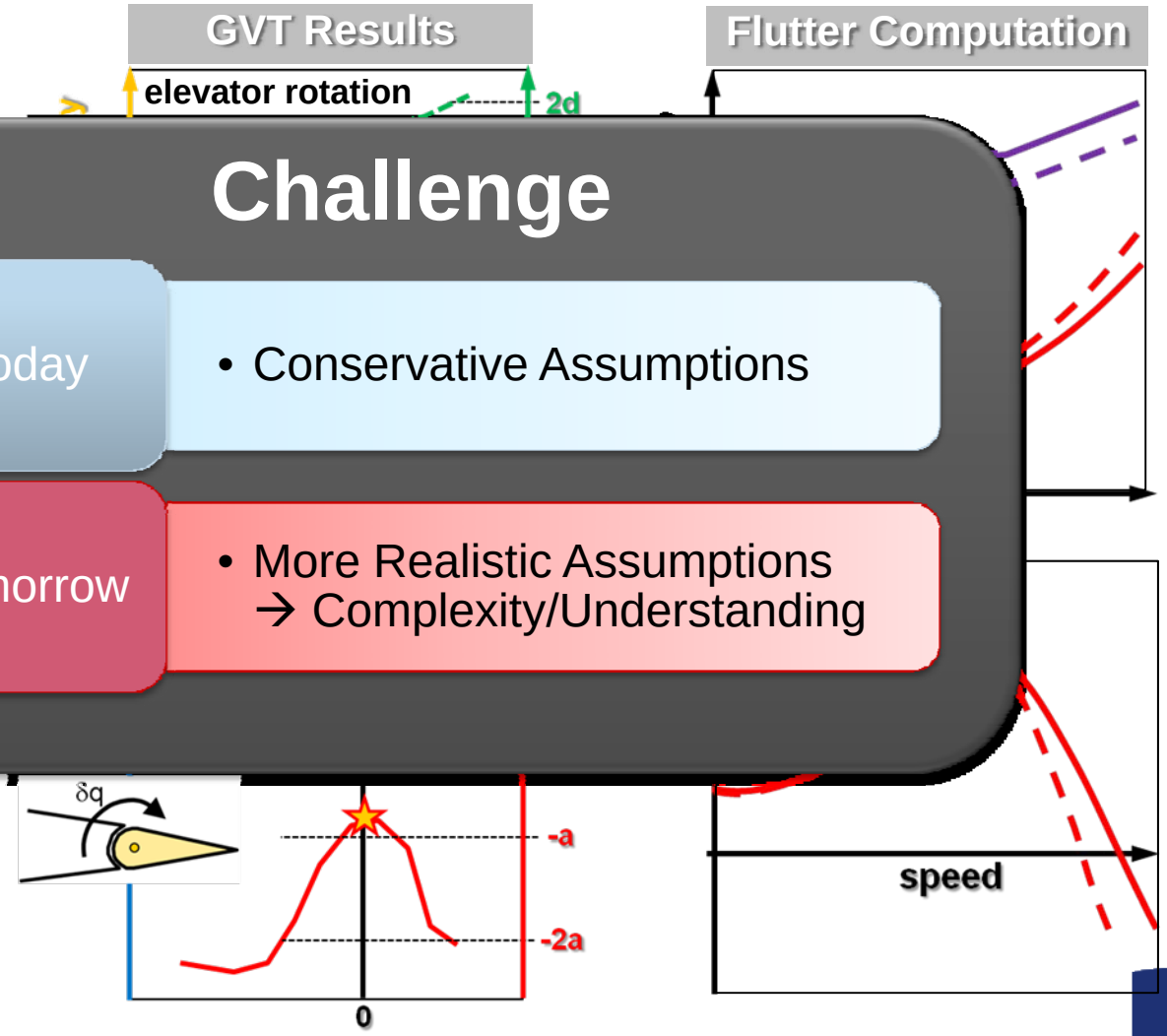
- Damping / Sti
  Dependency
  Excitation Fo

Aerodynamic Nc

- Hinge Momer
  Dependent or
  Deflection Amp

Challenge

Today	• Conservative Assumptions
Tomorrow	• More Realistic Assumptions → Complexity/Understanding



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Damping Prediction

A Real Research Challenge!

Damping Modeling

Today

Modal Damping: Global conservative estimate.

Tomorrow

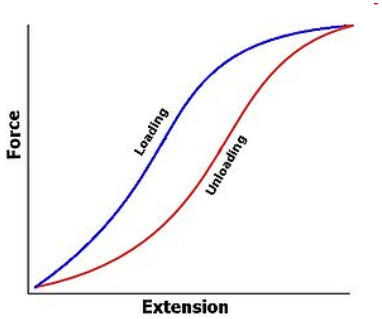
Ability to model relevant damping effects within standard FE analysis.

Challenge

Understand the origin and mechanisms of concentrated and distributed damping sources.

Find adequate models suitable for whole aircraft FE calculations.

Improve understanding of impact on overall aircraft response to guide design improvements.

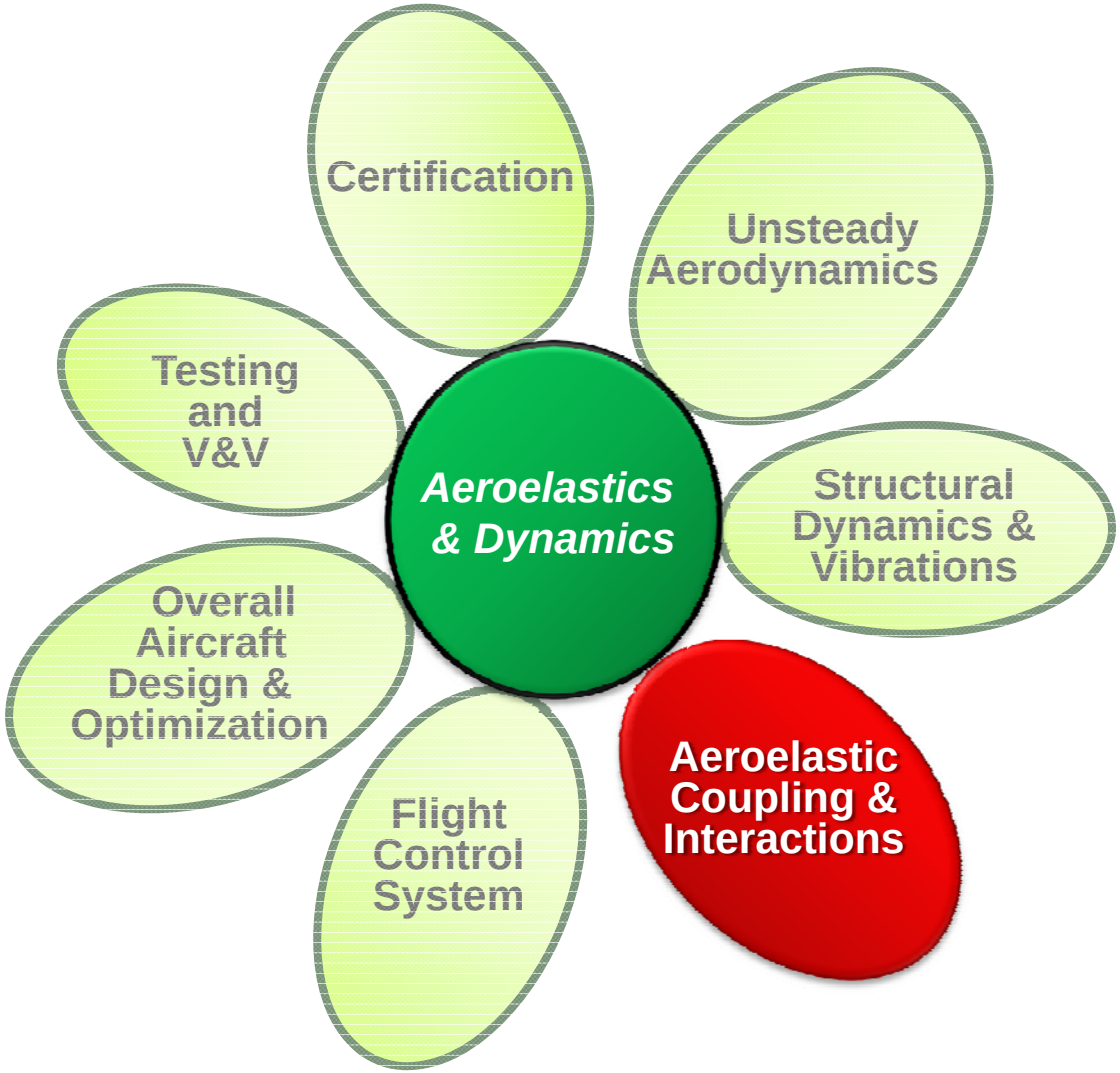


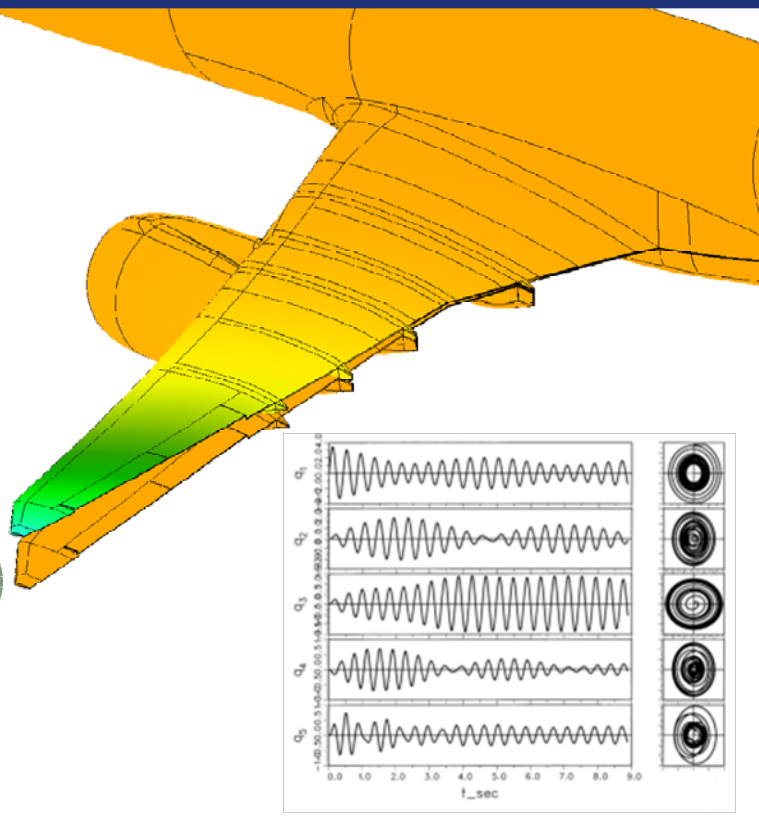
Benefits

→ Lighter Designs

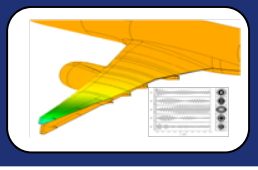
→ Reduced GVT

Aeroelastics Core Activities / Processes





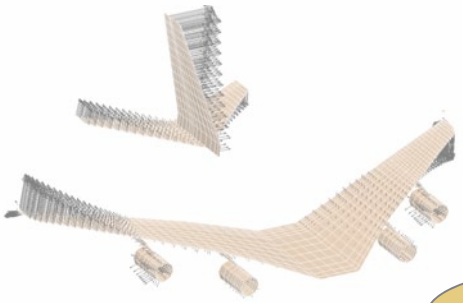
Aeroelastic Coupling & Interactions



Efficiency vs. Fidelity

Aeroelastic (Aero-Structure) Coupling

DLM

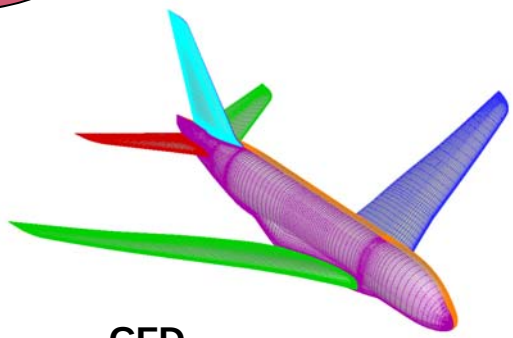


Standard Process

- **Efficient & fast**

CFD Process

- **Challenging & time-consuming**



CFD

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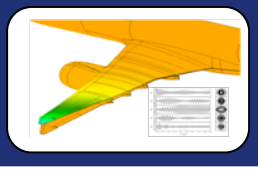
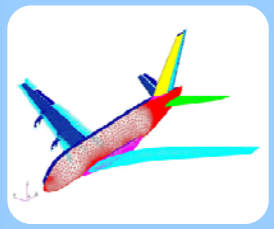
Aeroelastic Coupling & Interactions



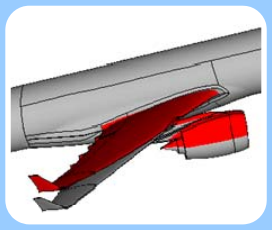
Computational Aeroelasticity

Three Major Bricks



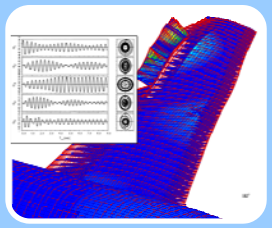
CFD/CSM Inter-grid Interpolation

- Accurate Force & Motion Transfer
- Splines, Mapping, Inter-/extrapolation



Static CFD/CSM Aeroelastics

- Steady Iterative Solution
- Non-linear Trim



Dynamic CFD/CSM Aeroelatics

- Unsteady, Time-marching
- Transient Response

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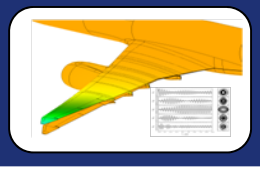
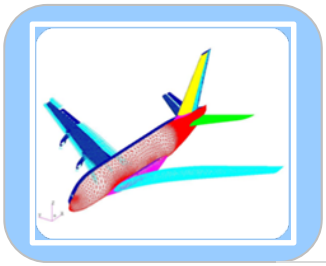


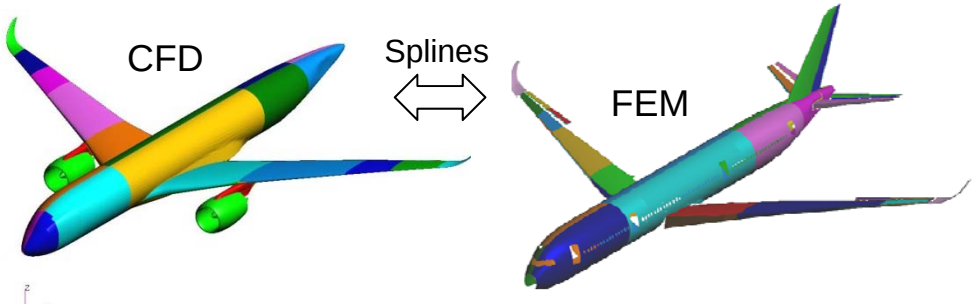


CFD/CSM Inter-grid Interpolation

Challenges

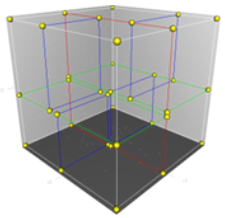
Model Build Rules & Automation

- Meshing
- Parts
- Blending
- Relaxation



Computational Efficiency

- Time for building spline matrix
- Size of spline matrix
- Distributed / parallel computation



Partition of Unity

Tree structures

Physical Nodal Loads

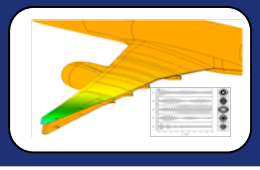
Direct Pressure Mapping

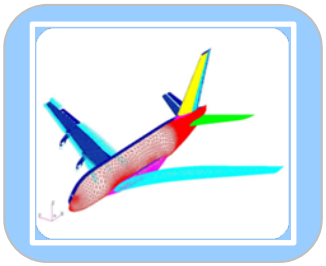
?

Spline Interpolation of Pressures

Quality/Accuracy

Aeroelastic Coupling & Interactions

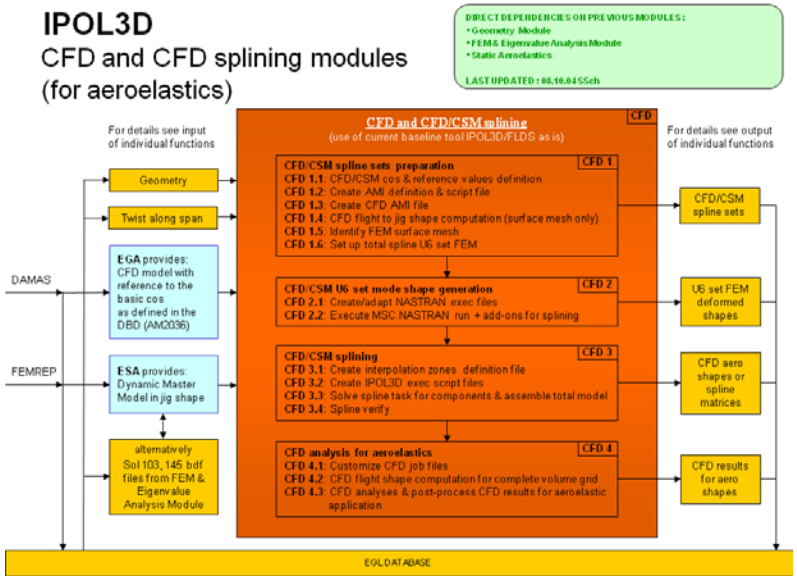


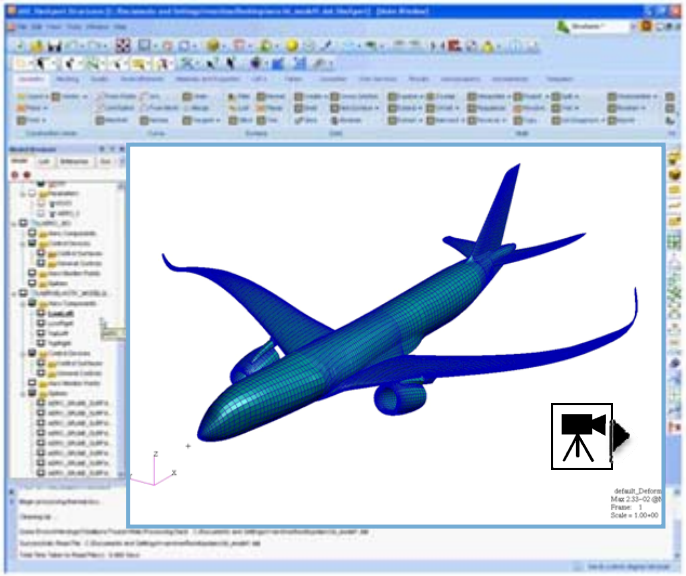


CFD/CSM Inter-grid Interpolation

Airbus / MSC.Software Technology Project

Transfer of Airbus in-house development to MSC SimXpert / MD Nastran Platforms





Features

- Simple and complex FEM
- Block-structured & unstructured/hybrid CFD
- Spline verification
- Component approach & Partition of Unity
- Advanced spline blending & relaxation (complex geom)

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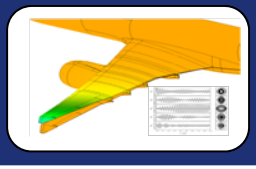
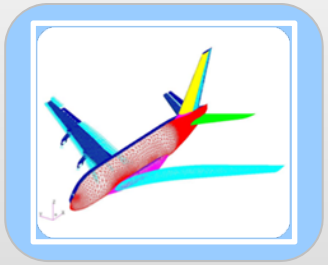
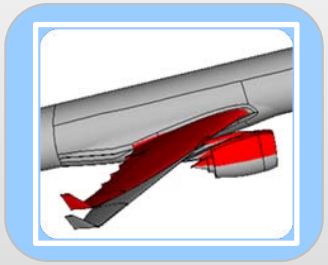
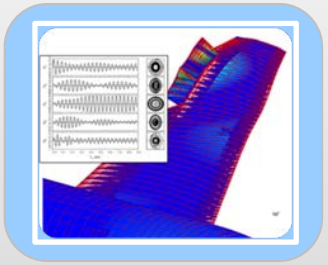


CFD/CSM Aeroelastics

Challenge







CFD/CSM Aeroelastic Toolbox

Applications Control

Common Data Bus

FlowSimulator

Common framework and integration platform using state-of-the-art HPC.

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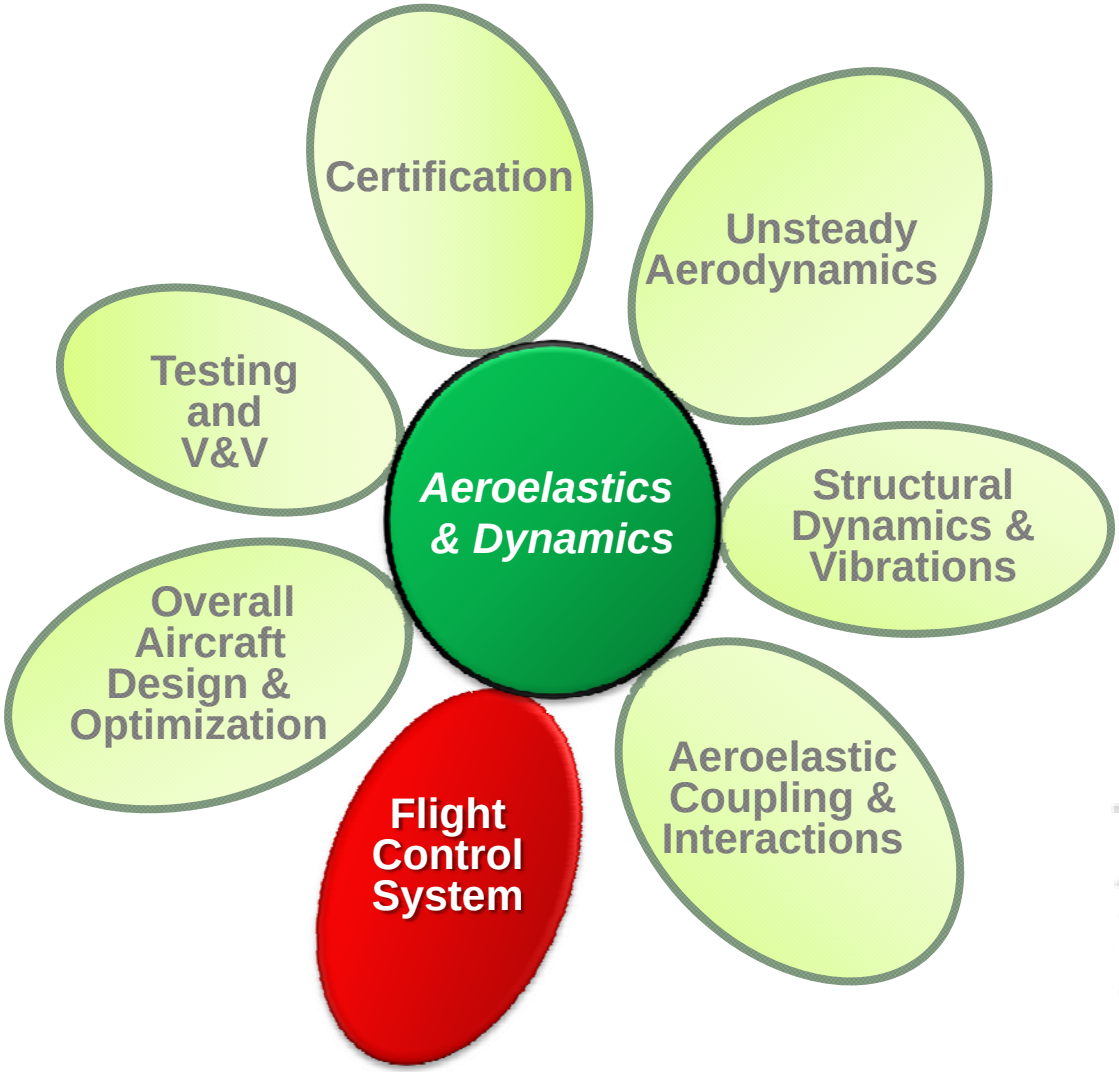
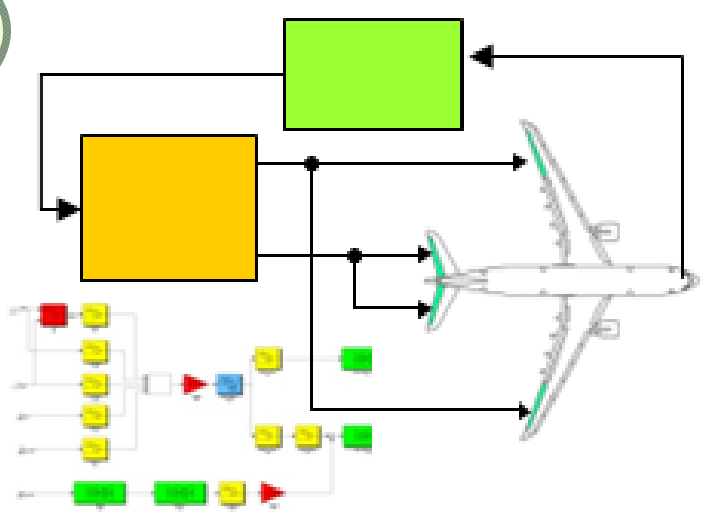
Aeroelastics Core Activities / Processes





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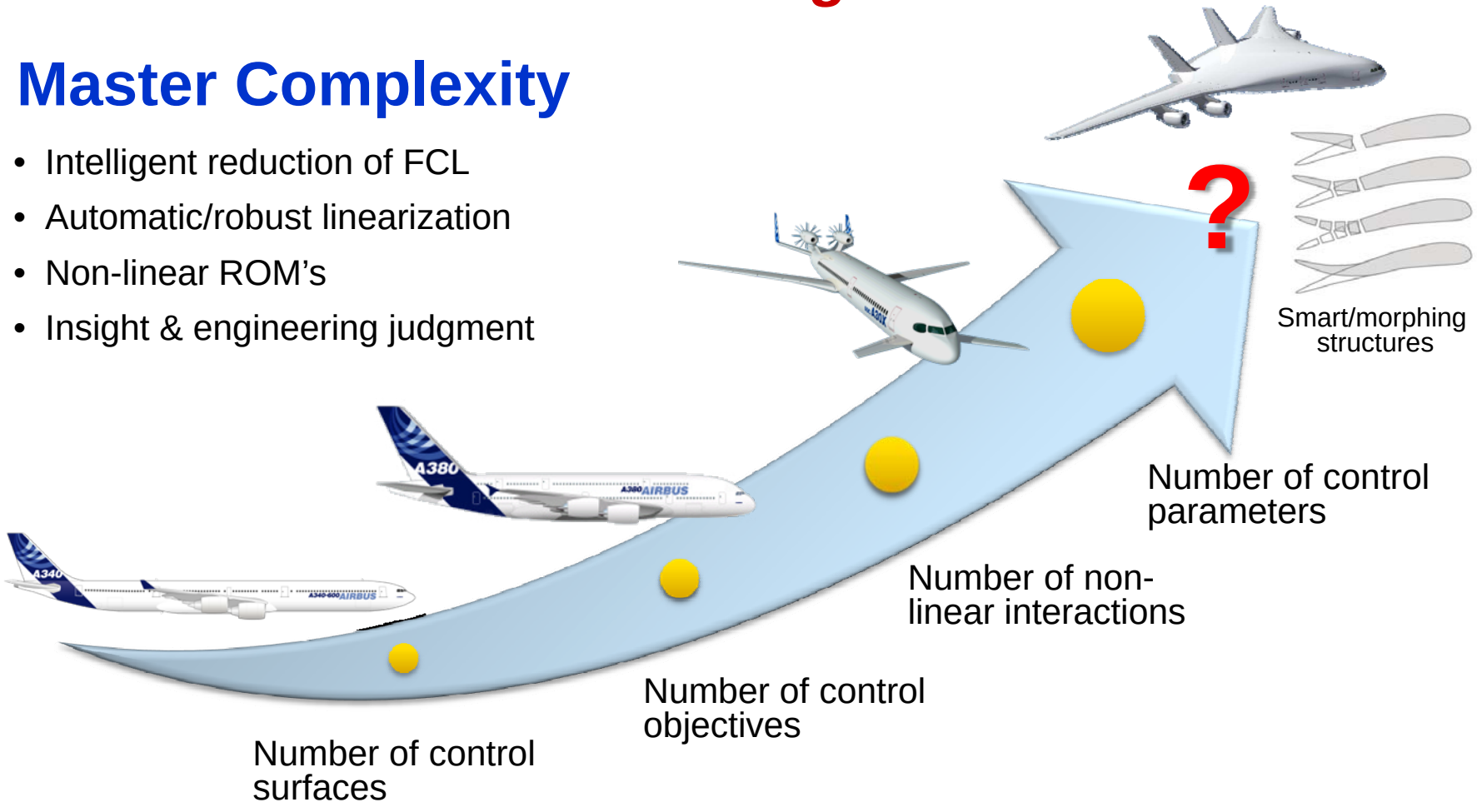
Flight Control System

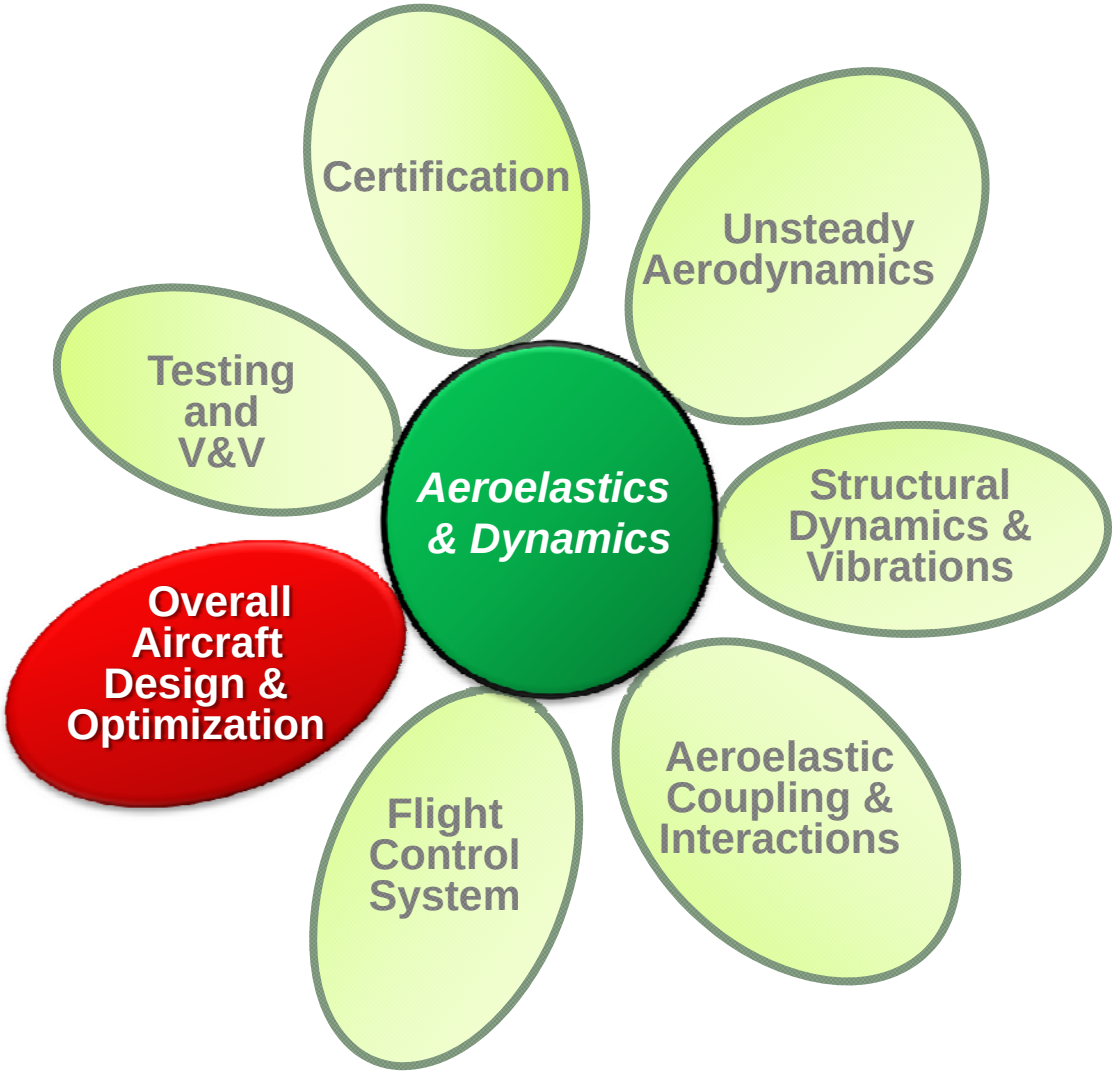
Challenge

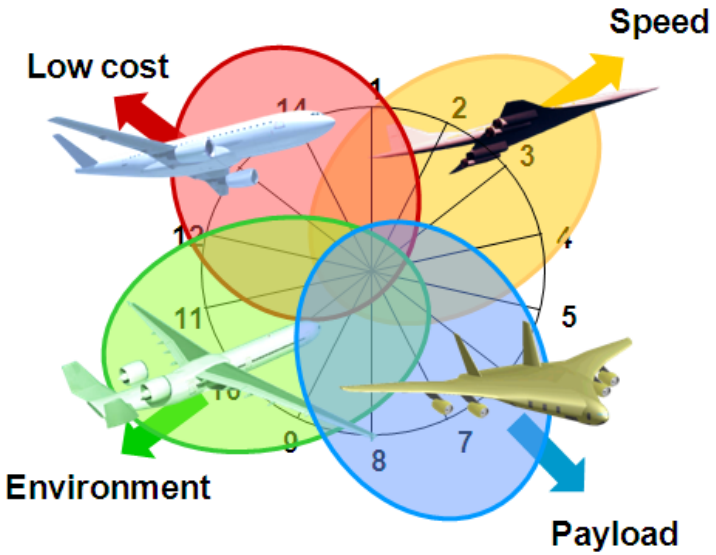
Master Complexity

- Intelligent reduction of FCL
- Automatic/robust linearization
- Non-linear ROM's
- Insight & engineering judgment

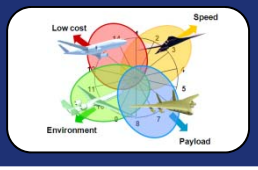


Aeroelastics Core Activities / Processes





Overall Aircraft Design & Optimization



Two Axes

Aeroelastic Performance

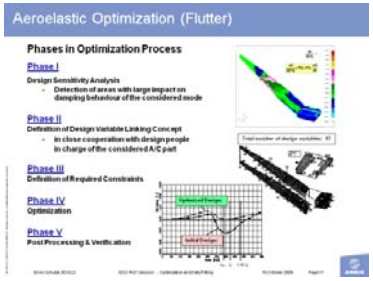
Structural optimization with respect to:

- Flutter
- CS effectiveness
- Stress/Weight

Aircraft Performance

Overall aircraft optimization with respect to:

- Aerodynamic performance
- Handling Qualities
- Loads/Stress/Weight



Multi-disciplinary problems solved by multi-functional teams.

Challenge

Establish an efficient aircraft design and configuration optimization capability taking full benefit of dedicated aeroelastic trade studies.

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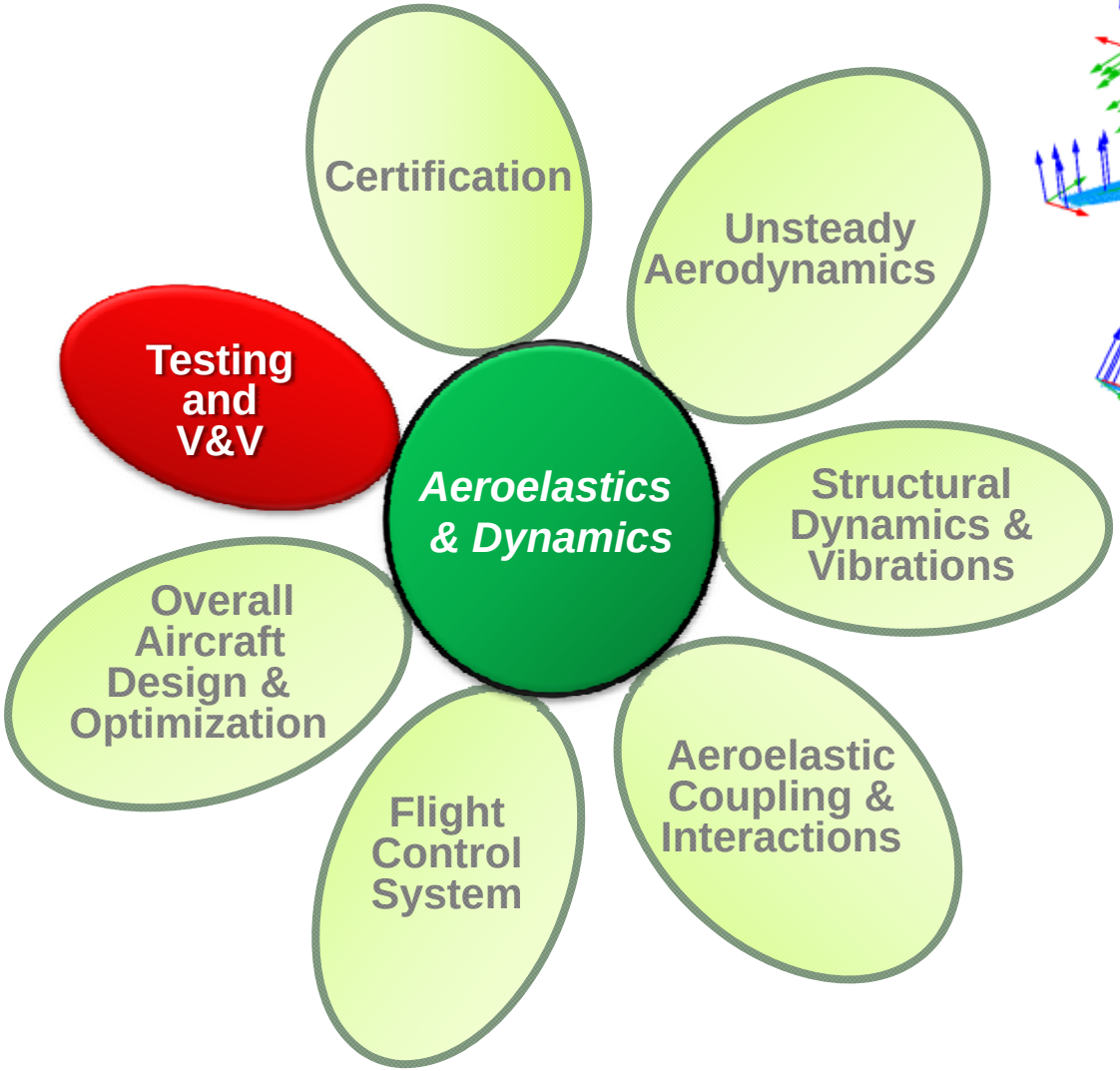
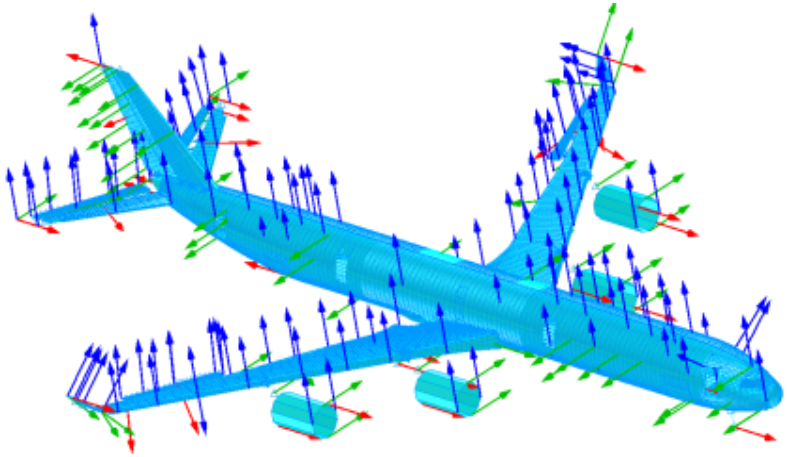
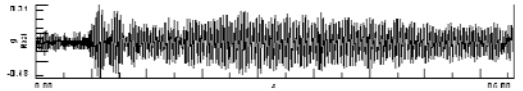
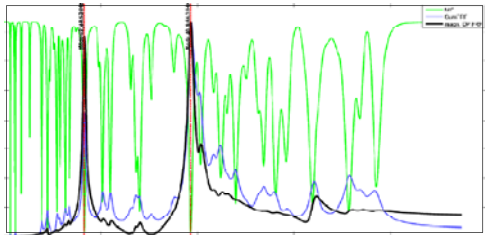
Aeroelastics Core Activities / Processes



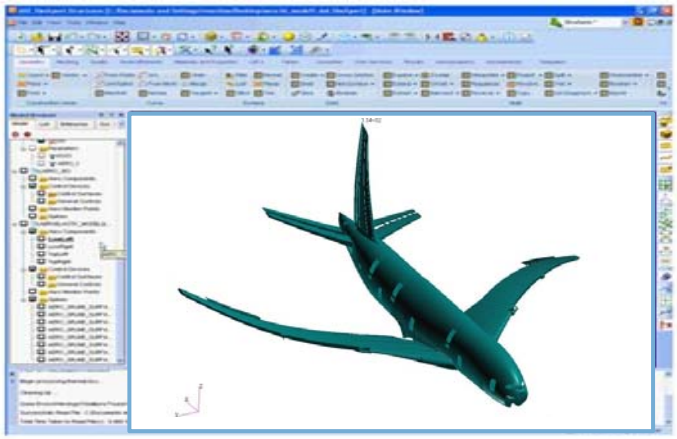






Testing and V&V

In the Computer

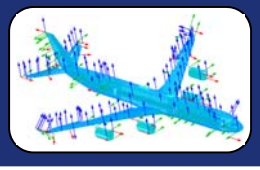


On Ground

In Wind Tunnel

In Flight

Testing and V&V



Challenge

How to master the increasing complexity of our products and reduce test effort at the same time?

Increasing pressure to reduce test effort

↓ Time & cost

Advanced technology aircraft

↑ Uncertainties

New V&V Strategies

Model Tuning Techniques

Test Performance & Quality

Management of Uncertainties

Advanced Simulation & Virtual Testing

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Questions

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