Aerodynamics

Computational Fluid Dynamics

Industrial Use of High Fidelity Numerical Simulation of Flow about Aircraft

Presented by
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AIRBUS

Contents

Aerodynamics is a Major Contributor to …

Overall Community & Company Vision

The European aviation community leads the world in sustainable aviation products and services, meeting the needs of global citizens and society.*)

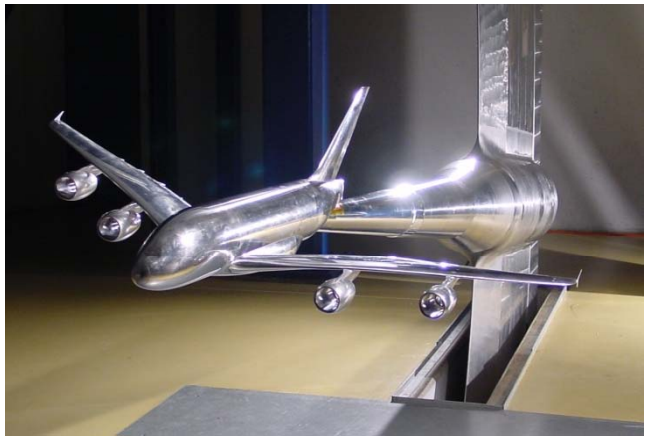
Major 2050 Goals**)

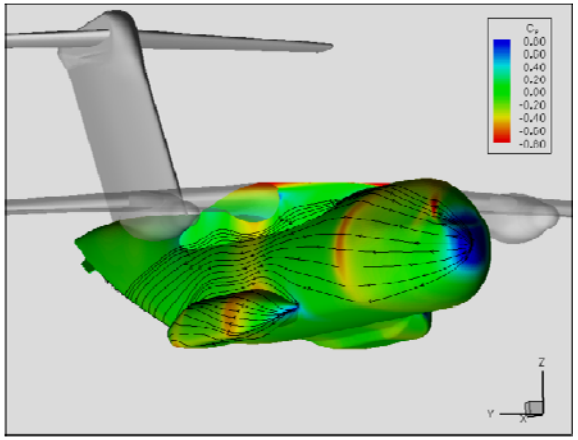
- ***CO_2 reduced by 75%, NO_x by 90% and perceived noise by 65%, relative to typical new aircraft in 2000***
- ***Certification cost reduced by 50% through leading new standards***
- ***Leading edge design, manufacture & integration maintained***
- ***Jointly defined European research and innovation strategies, from basic research to demonstrators***
- ***Strategic European aeronautic test, simulation and development facilities identified, maintained and continuously developed***

*) Flightpath 2050 Vision, supported by Airbus
**) agreed and presented in Flightpath 2050

Aerodynamic Simulation

Method	Experiment	Theoretical / Numerical
Simulation machine	Wind tunnel Flying aircraft	Computer
Model	„Real“ image	Physical / mathematical models of nature





- Both types of simulation do have advantages, drawbacks and limits
- Both techniques complement each other
- Both methods are further being needed and developed

Computational Fluid Dynamics – the Principle

CAD
CATIA V5

- **Geometry, flight conditions**

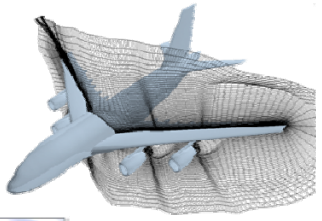
- **Physical model of flow**

$$\frac{\partial}{\partial t}\int_V \vec{W}\,dV = -\oint_{\sigma V} \vec{\bar{F}}(\vec{W}) \cdot \vec{n}\,d0$$

conservation laws of nature – 5+2 equations

Mesh Generator
ICEM/Centaur/SOLAR

- **Discretization**



10-50 Mio. mesh points

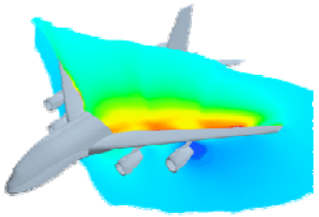
Flow Solver
elsA/TAU

- **Numerical Solution**

0.915476 0.934722 0.995642
0.936521 0.968456 0.973853
50-350 Mio. numbers

Postprocessing
FFDx/ENSIGHT etc.

- **Evaluation**

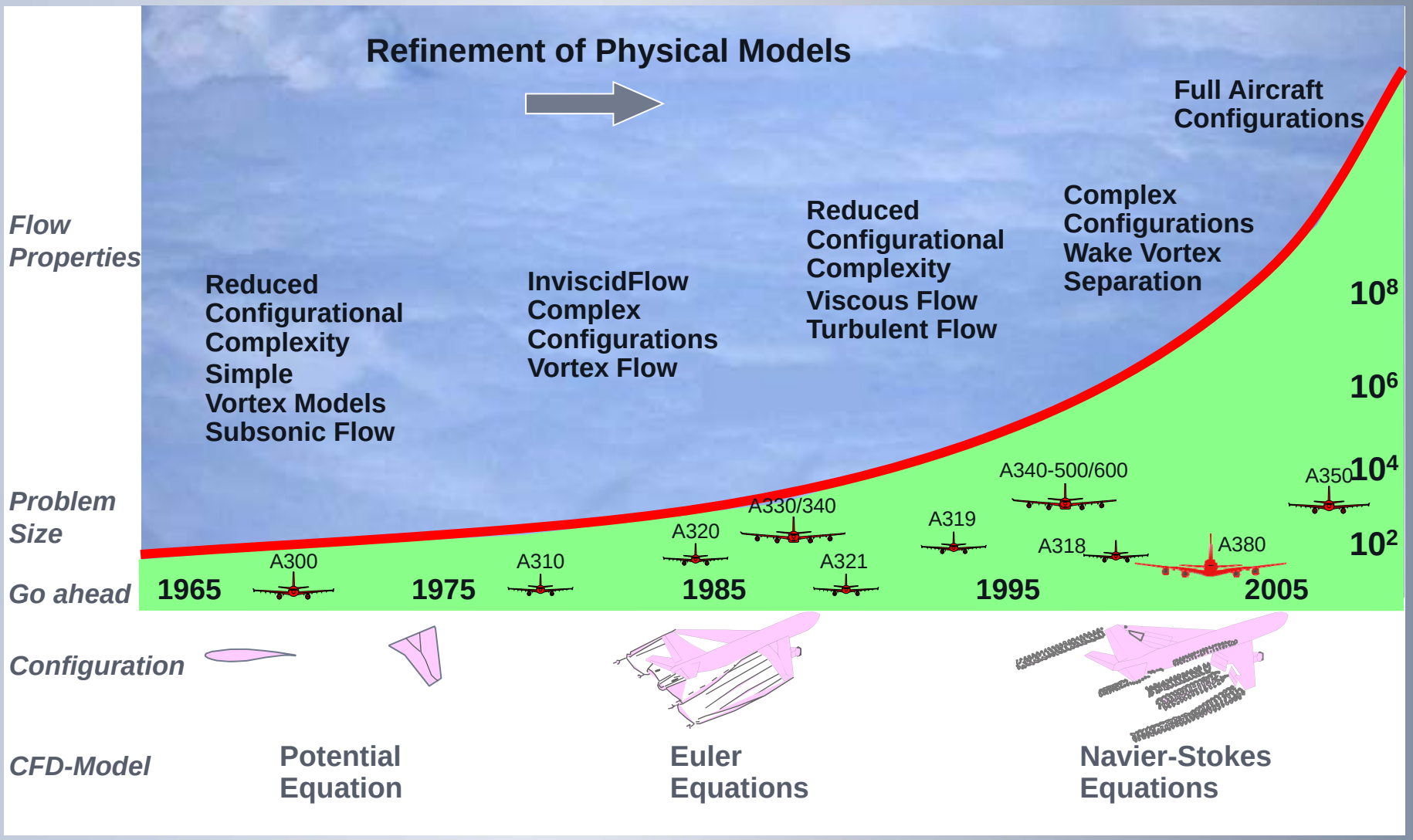


Lift: 0.5
Drag: 0.025
Moment: -0.08

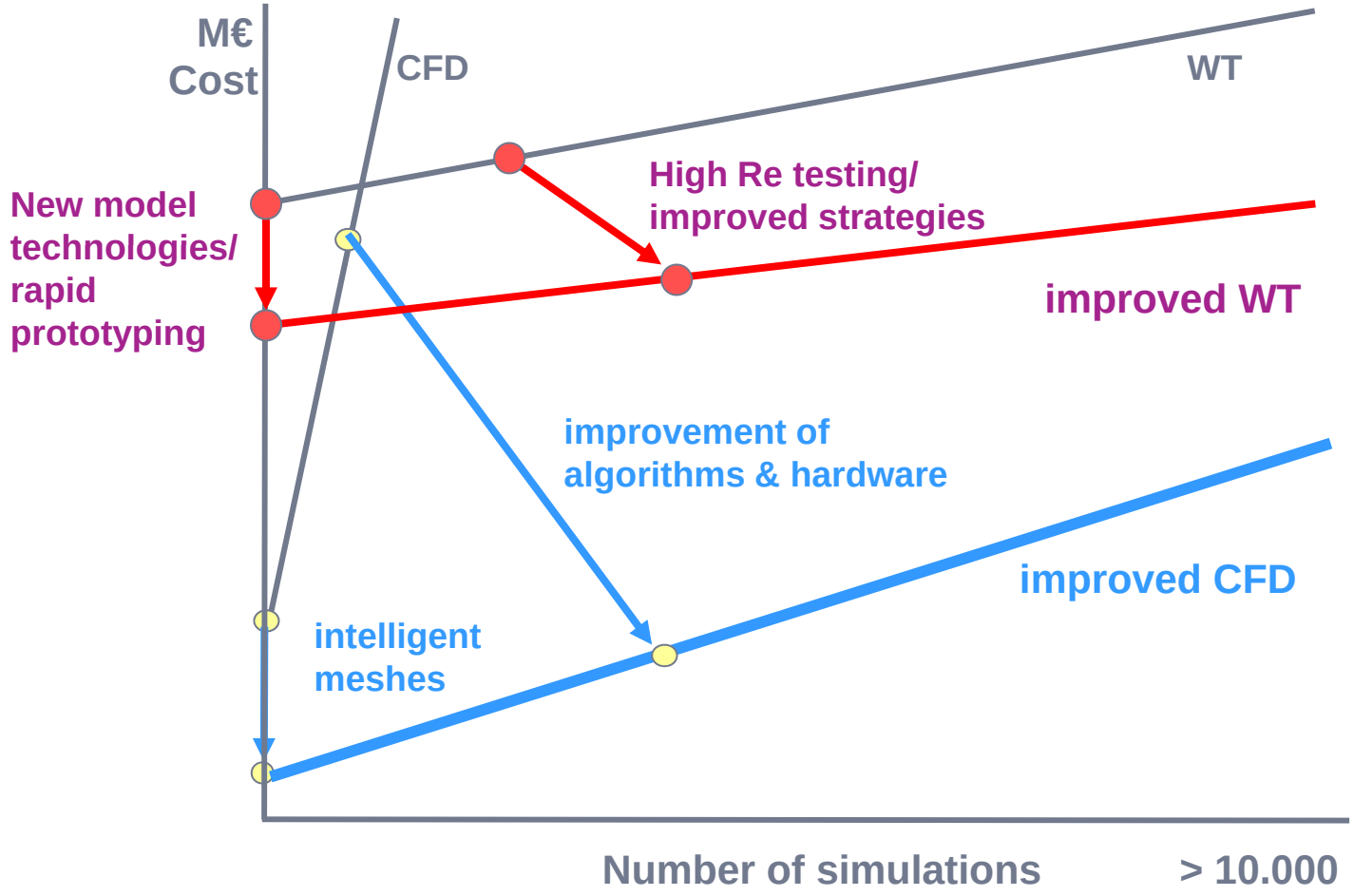
- **Flow, Aero Data**

Problem: Quality ⇔ Discretization error ⇔ Size of task ⇔ Cost/time

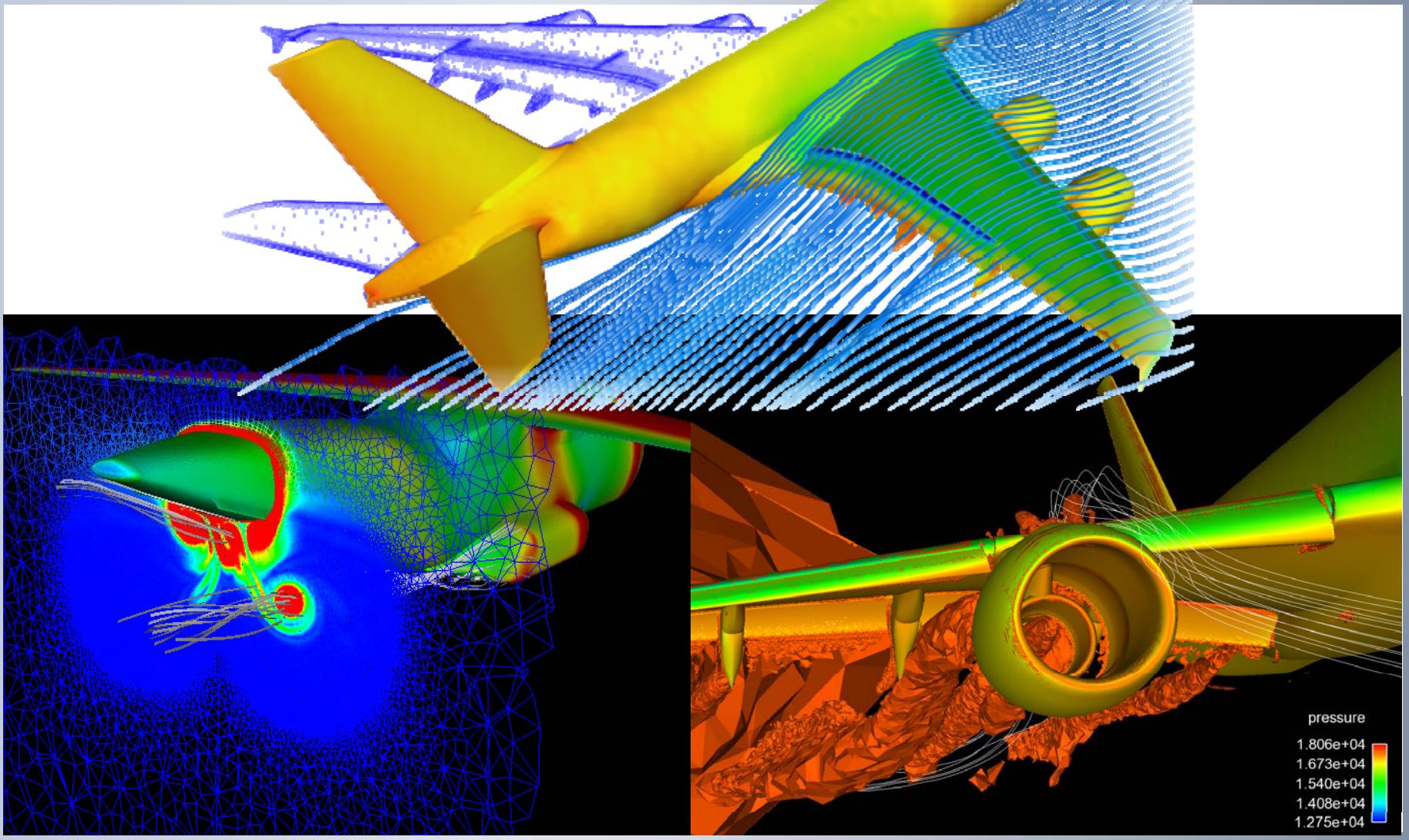
CFD Models



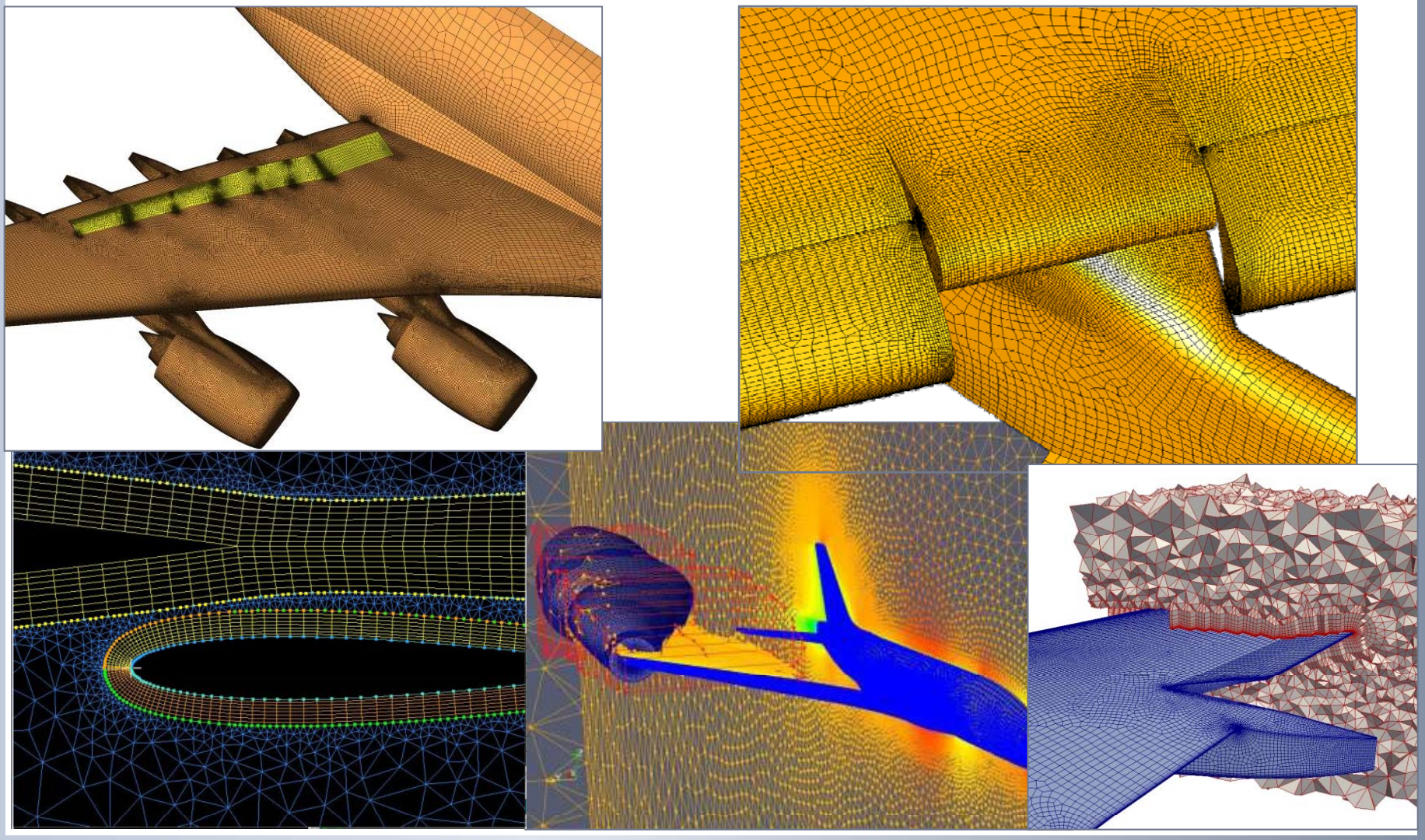
Expected Improvement Lines for CFD/WTT



CFD

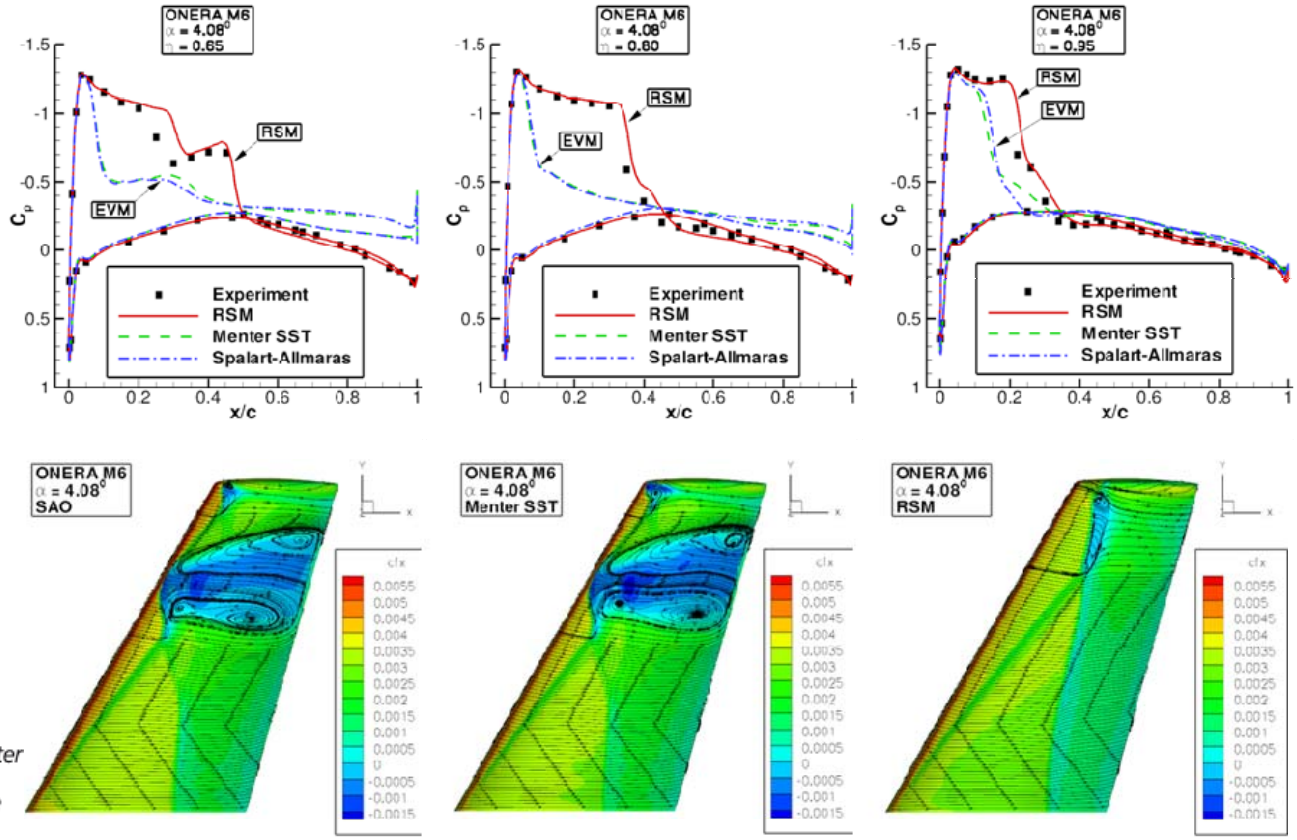


CFD Status: mesh generation



CFD Status: Flow physical modelling

- Significant improvement in flow modelling
  - RSM turbulence model clearly favourable to classical 1- or 2-eqn models
  - Much better prediction of shock-induced separation



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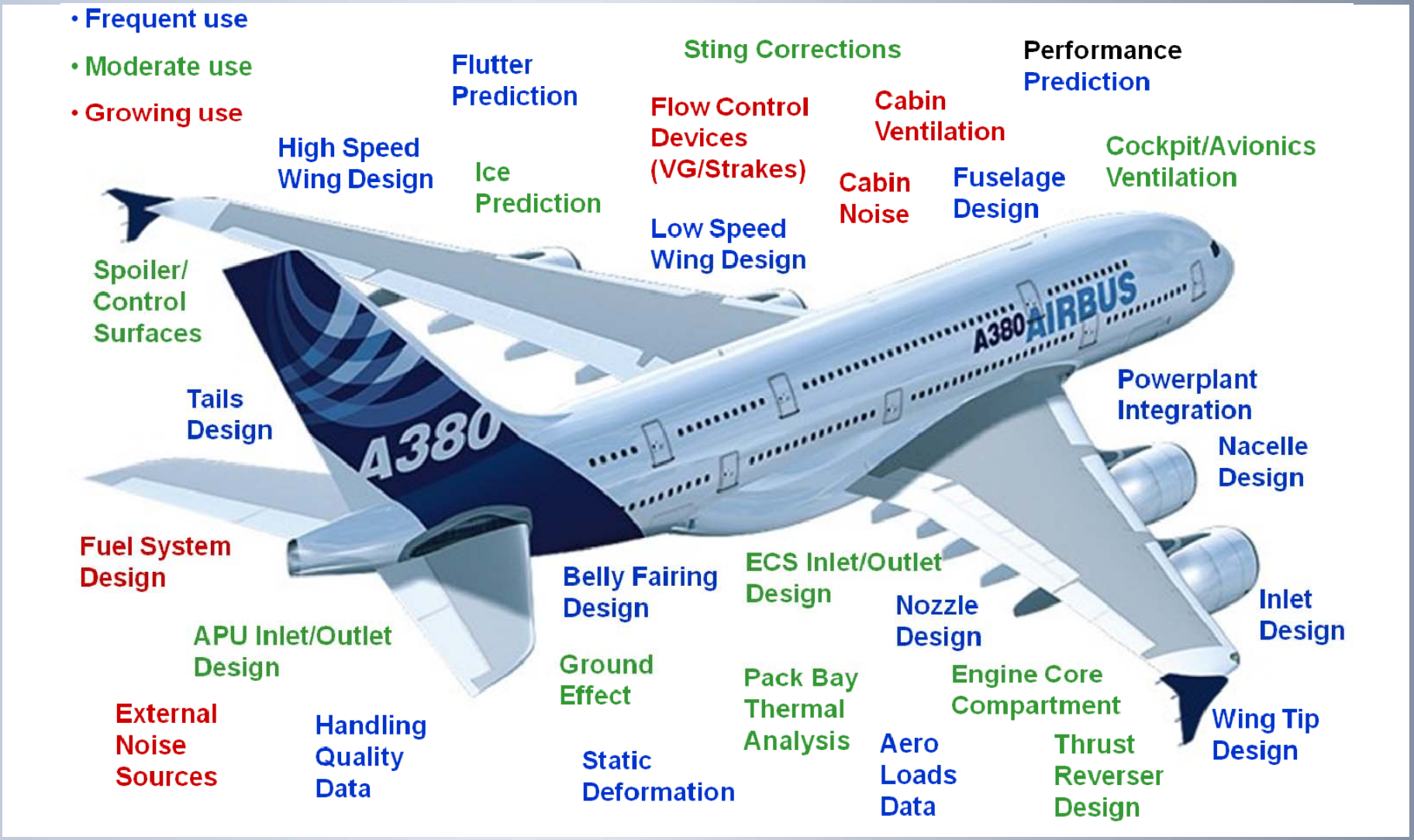
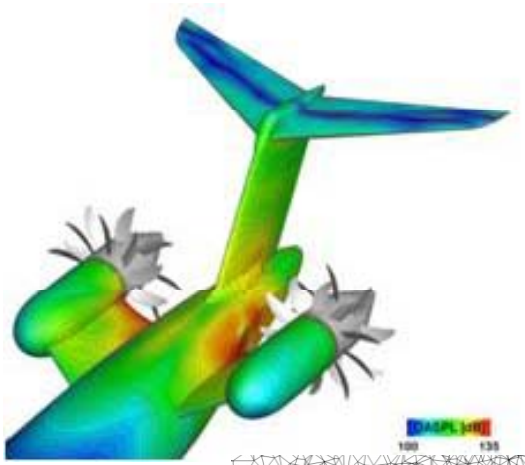
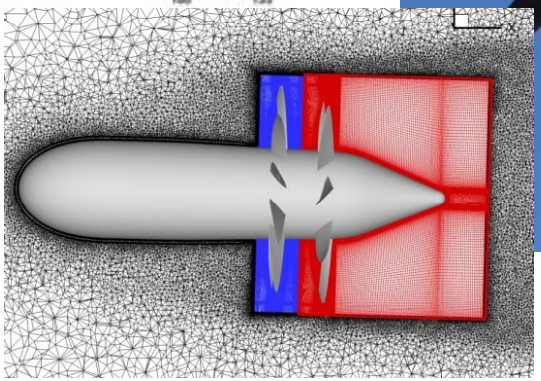
Use of CFD



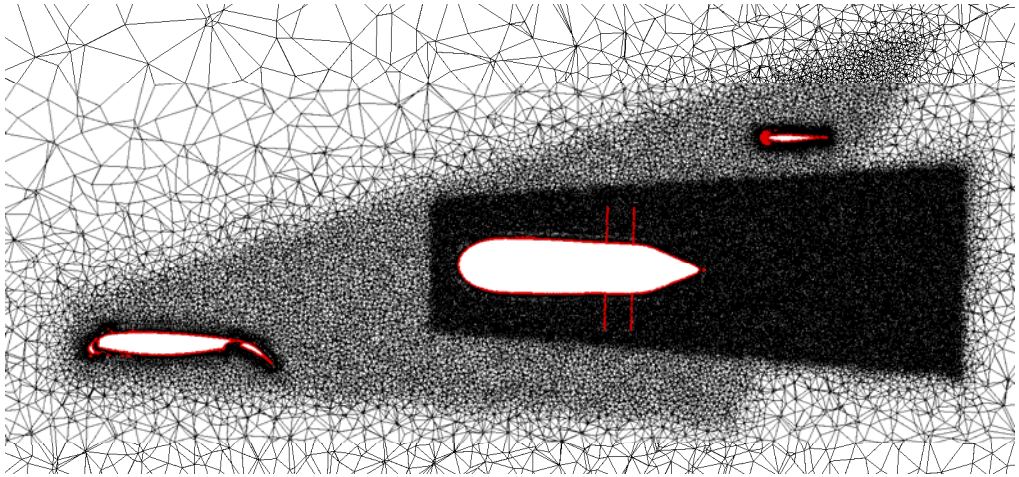
CFD Purpose: Predict Unsteady Aerodynamic Effects

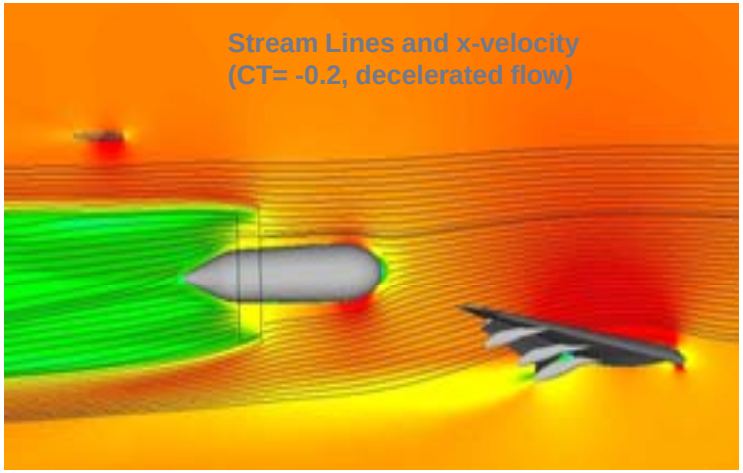
- Unsteady simulation on installed rotor configuration
  - Validation investigation on A400M and IPEKA test models
  - Chimera mesh technique with combined structured & unstructured meshes

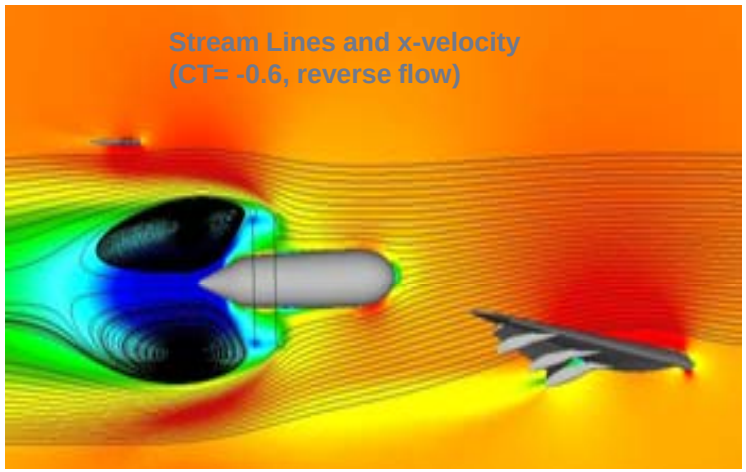




CFD Purpose: Support engine integration

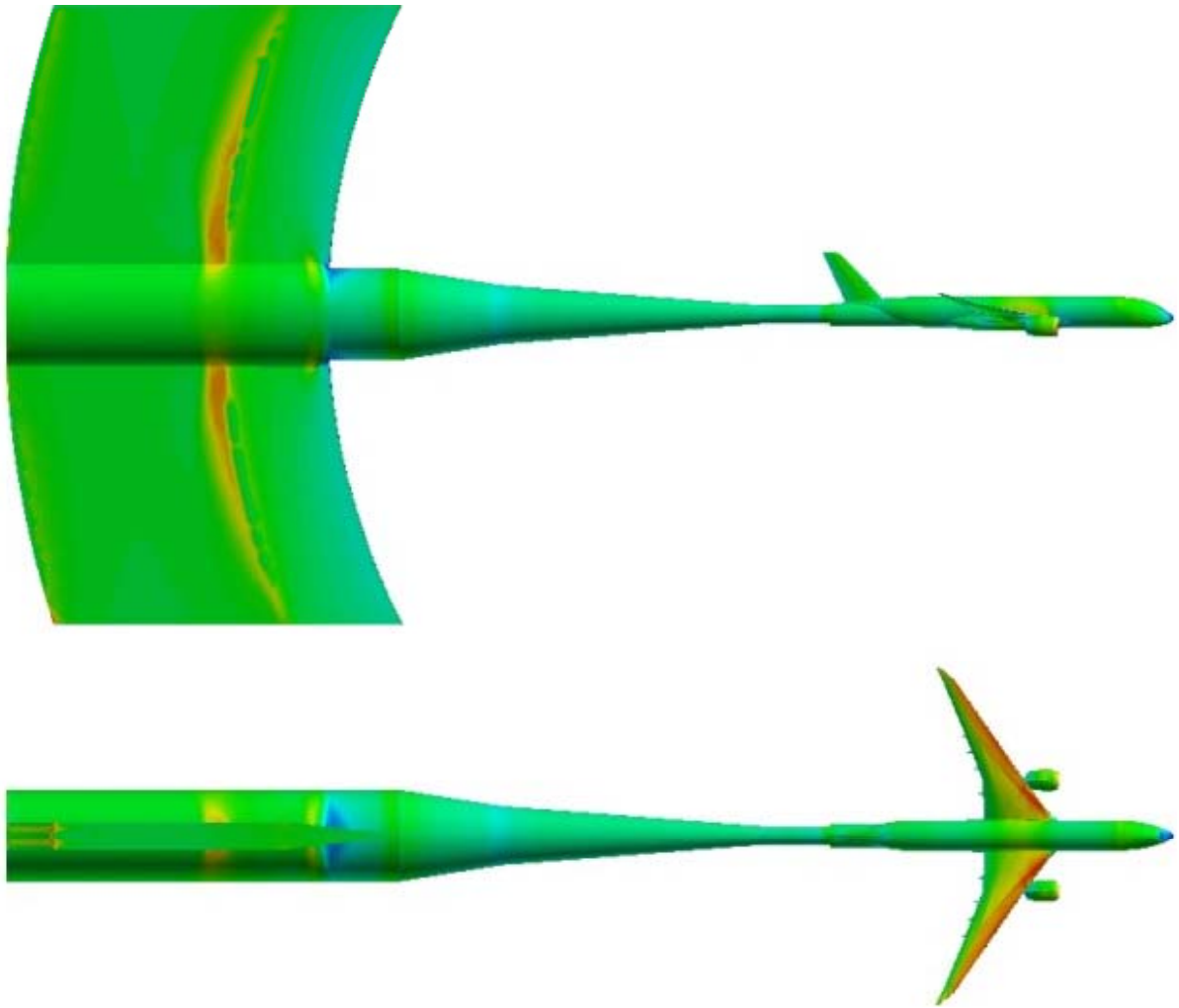






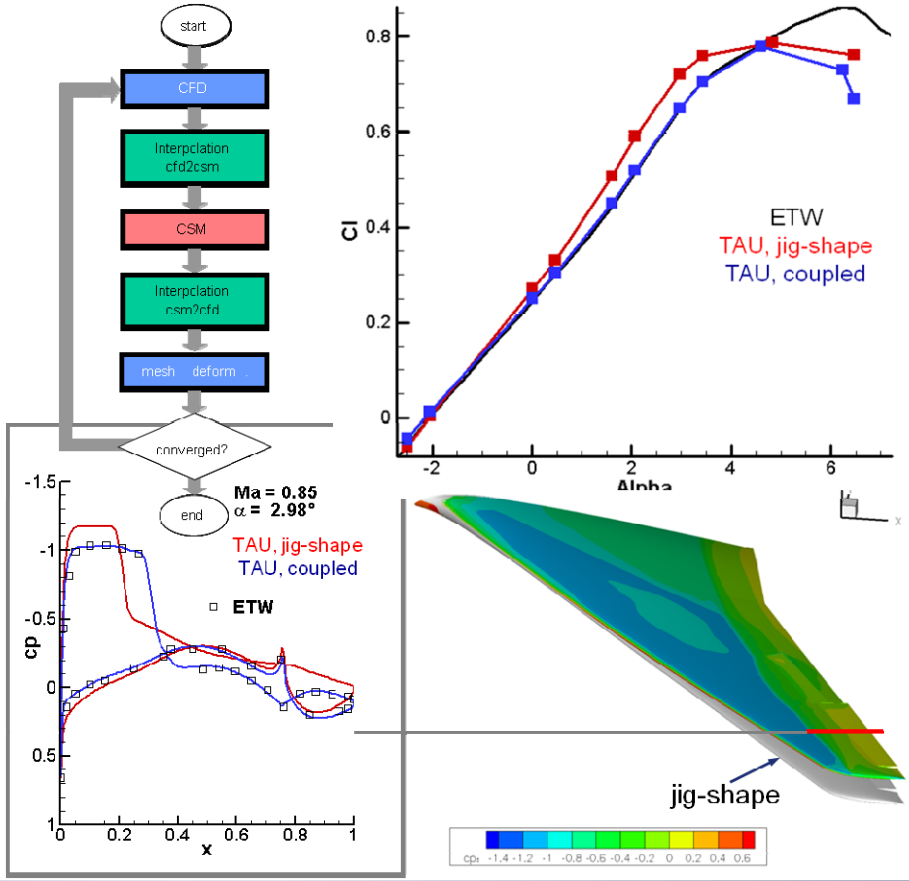
CFD Purpose: Support WT test set-up and analysis

- Consistent CFD application helps to understand WT results and create confidence
- Lessons learnt: best match with WT only via complete simulation of experiment (support, flexibility, walls, ...)



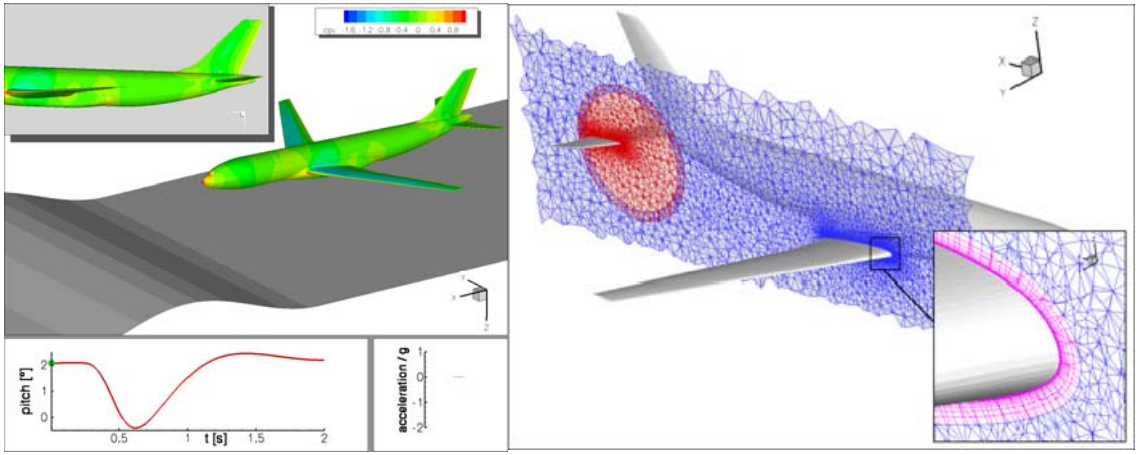
CFD Purpose: Predict Aerodynamics on “true” shapes

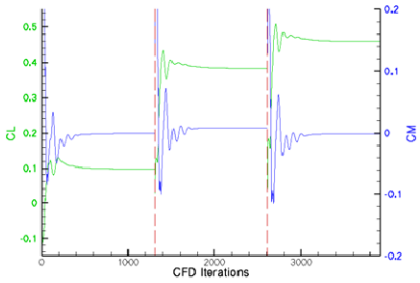
- High Fidelity CFD/CSM applied to aileron/spoiler case
  - Validation of CFD/CSM model on ETW wind tunnel data
  - Mesh deformation and CFD-CSM transfer interfaces independent of specific CFD



CFD Purpose: Aircraft unsteady aero loads

- Gust encounter simulation for flexible trimmed aircraft
  - Full MD simulation of standard gust affecting aircraft, incl. flexibility and trim
  - Multiple iterative coupling with automated process control





Trim-iteration convergence

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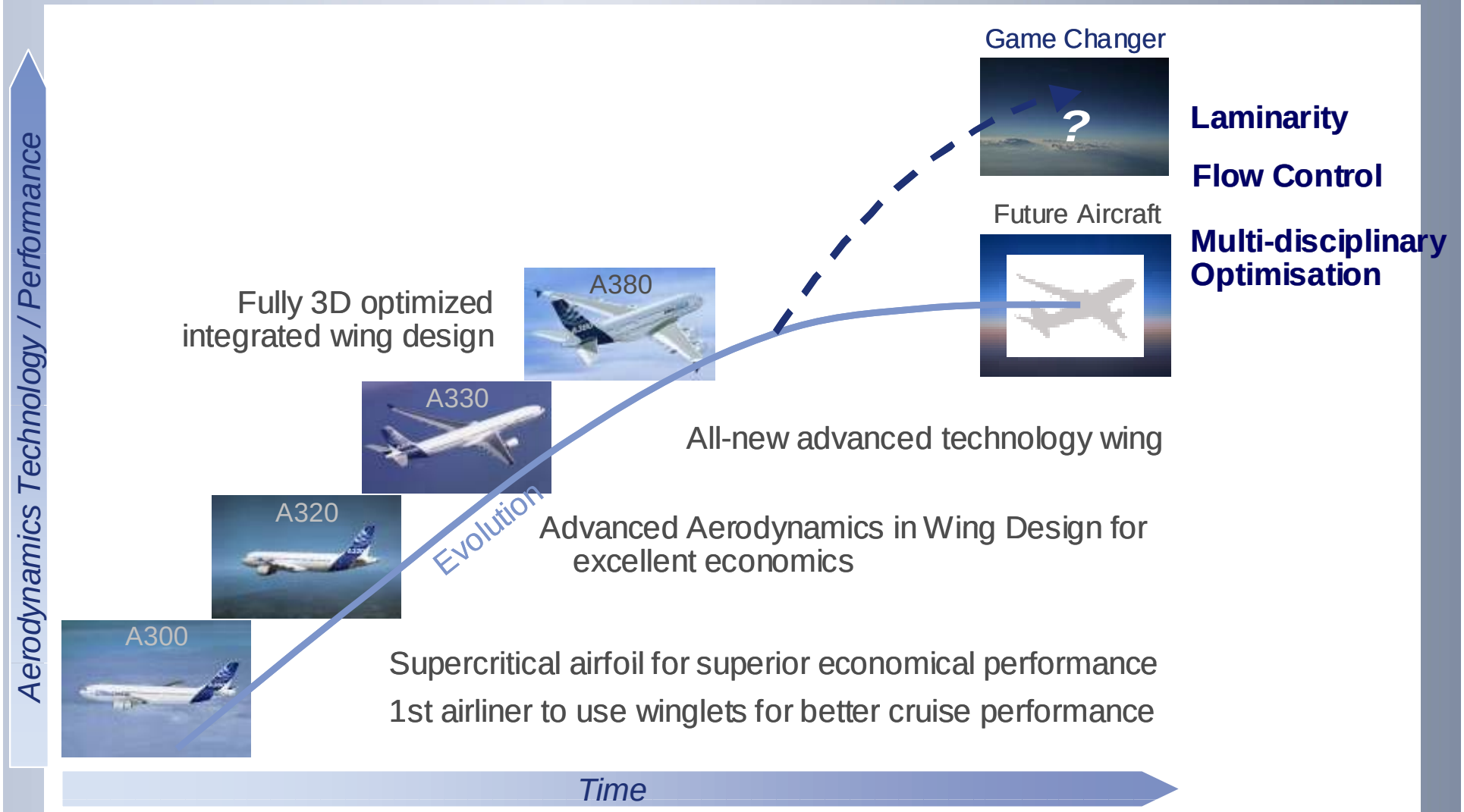
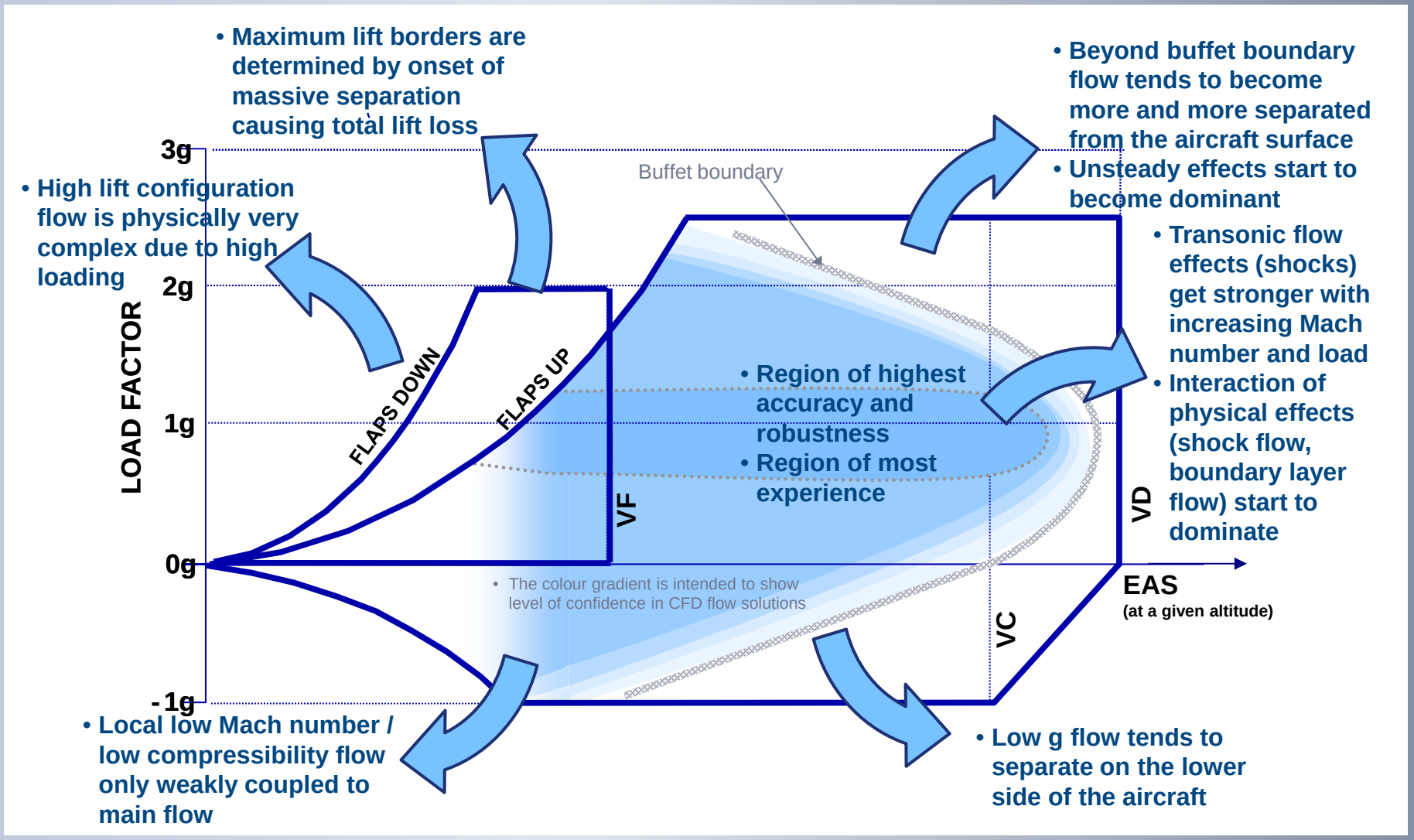
The Future



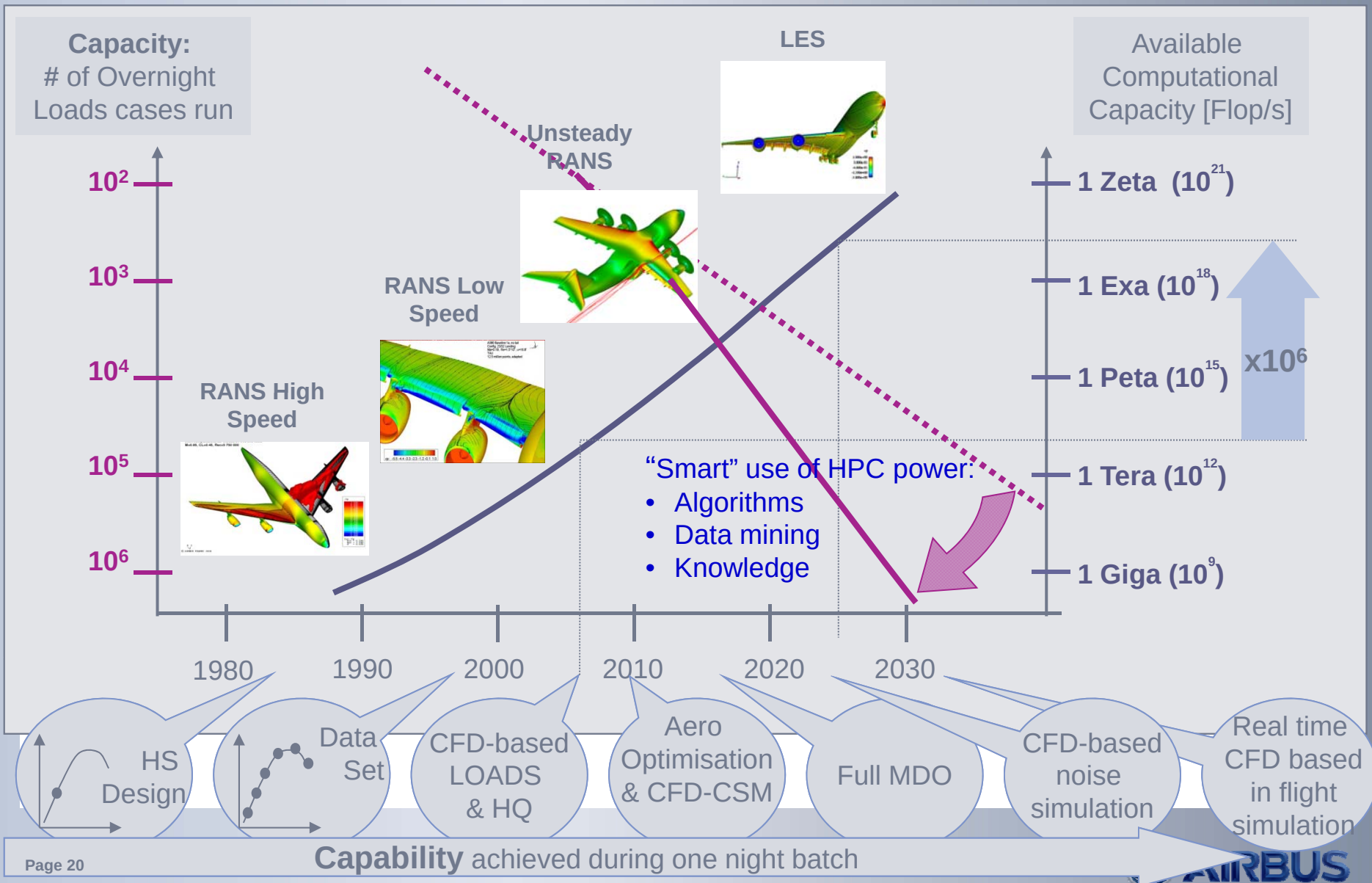
Future Expectations on Numerical Simulation

- By the power of the future simulation capability, multidisciplinary simulation and optimisation will be at hand of every Flight Physics engineer
  - Quality of the simulation will be appropriate for product development
  - Turn-around of simulation will be such that the engineer will not be faced with major interruptions of his work process
- There is a strong tendency and need towards multi-disciplinary simulation and optimisation across Flight Physics
  - MD interaction will be fully implemented in FP simulation capability
  - Numerical optimisation will provide baseline design as well as improvement steps, it will widely assist the design engineer
- Numerical simulation will be the major source of all FP aircraft data
  - Comprehensiveness as well as quality of data is accepted by related customers/authorities
  - Physical experiments will only back-up/validate numerical data

Flight Envelope Flow Physics Challenges



HPC is a key to future



CFD: Request for “real-time”

21st Century Challenge

Challenge:

“Fly the Navier Stokes equations and NOT a database!

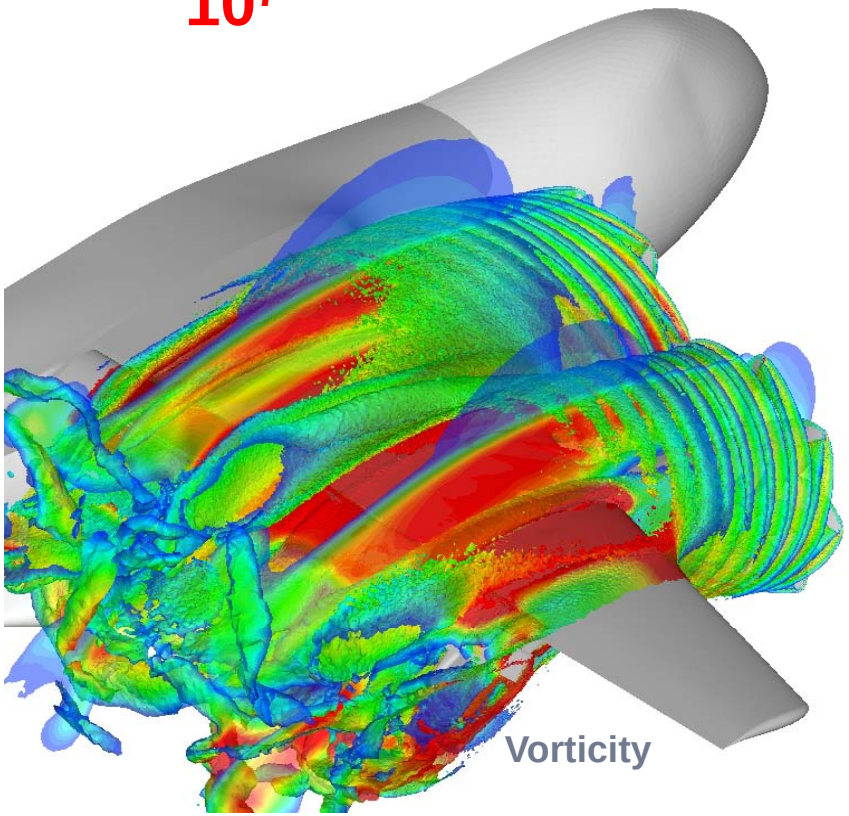
Accurate loads throughout the flight envelope

Current solution: 600cpu hours, 10 wall hours

The challenge: 50 solutions per second

The factor needed is 10^6

The factor needed is 10^7



Vorticity

Numerical Simulation Capability – 5 Corner Stones

- High fidelity aerodynamic simulation
  - High Fidelity Flow Simulation CFD capability
- Full parametric product definition
  - Parametric aircraft - shapes and aero data model
- Multi-disciplinary product optimisation
  - Integrated product simulation and optimisation
- Highly efficient numerical simulation & optimisation
  - Platform backbone software system
- High performance computing
  - Latest processor and hardware architecture