AERONAUTICS MULTIDISCIPLINARY APPLICATIONS ON GRID COMPUTING INFRASTRUCTURES

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COOPERATION

PROMOTING SCIENTIFIC COOPERATION BETWEEN EUROPE AND CHINA IN THE FIELD OF MULTIPHYSICS MODELING, SIMULATION, EXPERIMENTATION AND DESIGN METHODS IN AERONAUTICS

Promuval

PROSPECTIVE STUDY ON THE STATE OF THE ART OF MULTIDISCIPLINARY MODELING, SIMULATION AND VALIDATION IN AERONAUTICS

INGENET

MACSI-net
MAthematics, Computing and Simulation for Industry

DECISION

FLOWNET

RESEARCH CENTRES AND UNIVERSITIES

Multi-Physics Modelling , Numerical Analysis, Experimentation, Design

Web based activities

INDUSTRIES

Critical industrial multi physics problems

GOVERMENTAL INSTITUTIONS

Generic multi physic data

AEROCHINA Communication System

Simulation, Experimentation and Design methods

Database

AEROCHINA Data Base
Workshop
Road map

Aeroelasticity

Aero/vibro acoustics

Thermal flows

Fluid atmospheric environment

Noise prediction and reduction

Pollution prediction and reduction

Drag prediction and reduction

Safer design

Aeronautics

Propulsion

Other Network connection:
PIVnet
FLOWnet, Qnet, ERCOFTAC, PROMUVAL, EUROSHOCK, AEROMEMS, AEROLIFT, HISAC, TAURUS, EUROPIV, ENABLE, JEAN,...

GOALS

Foster the **cooperation between** industry, university and research **organizations** in the **aeronautics** sector in **Europe** and **China** in the field of mathematical modelling, computer simulation and code validation, experimental testing and development of design guidelines methods for the solution of multiphysics problems of interest to the aeronautic sector.

Roadmap

To identify and collect state of the art information on existing mathematical models and computational methods in Europe and China for analysis of multidisciplinary problems in aeronautics.

To collect state of the art information on test case problems and experimental data available in Europe and China for validation of computational methods for analysis and optimization of multidisciplinary problems in aeronautics.

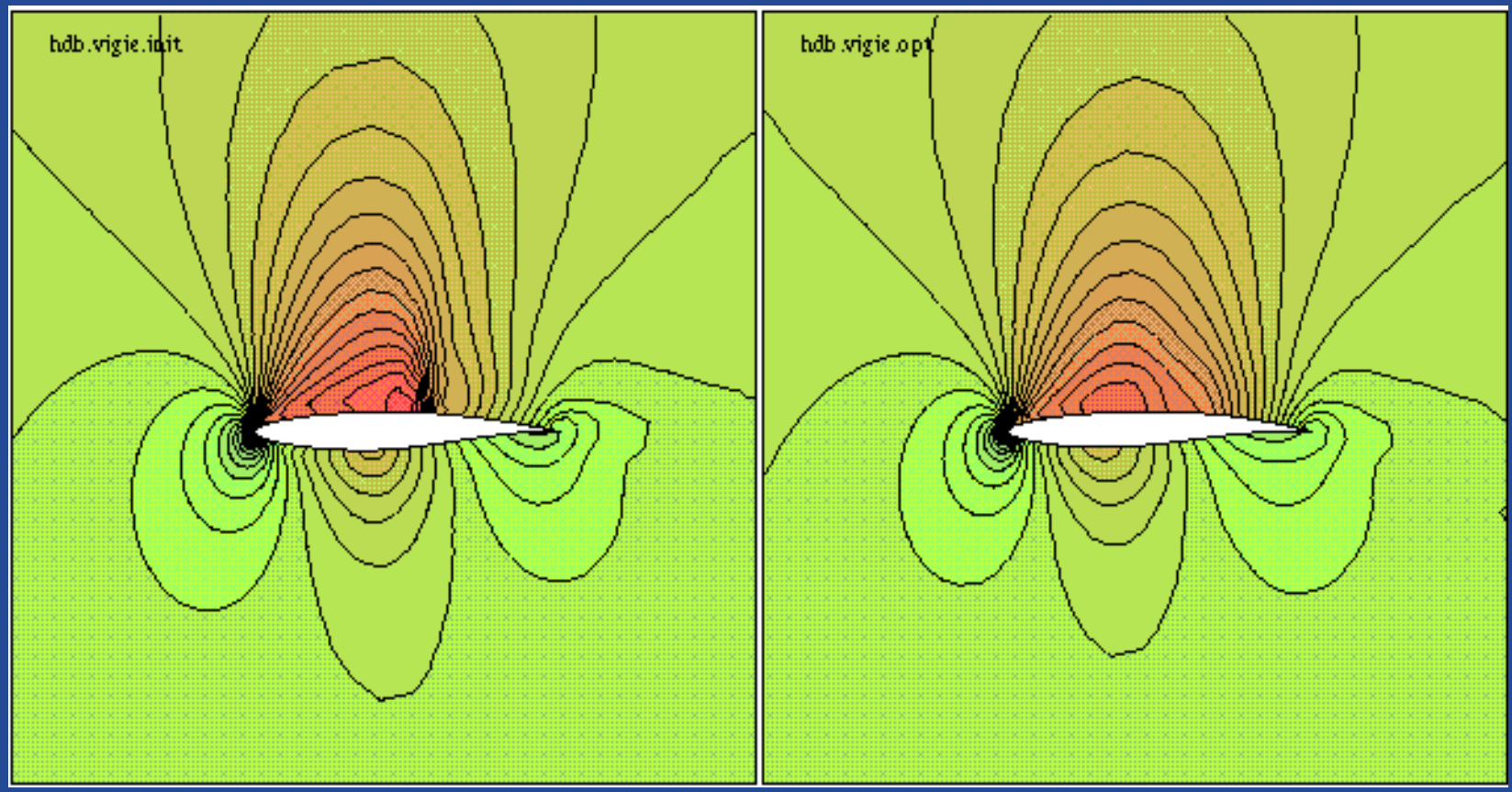
To identify critical future joint RTD areas in Europe and China for analysis and optimization of multidisciplinary problems in aeronautics using innovative computational methods and experimental tests.

To disseminate within Europe and China numerical and experimental data collected.

To define a strategy for analysis and design of multidisciplinary problems in aeronautics of interest to European and Chinese industry.

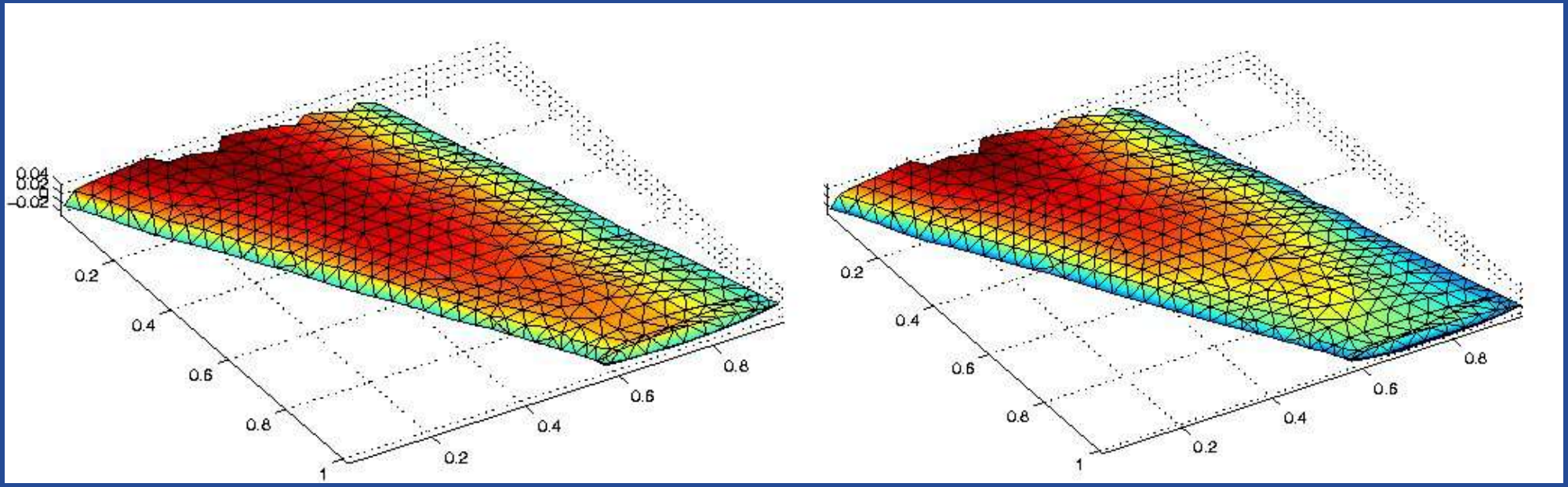
“STANDARD” TEST CASE

WING PROFILE OPTIMISATION



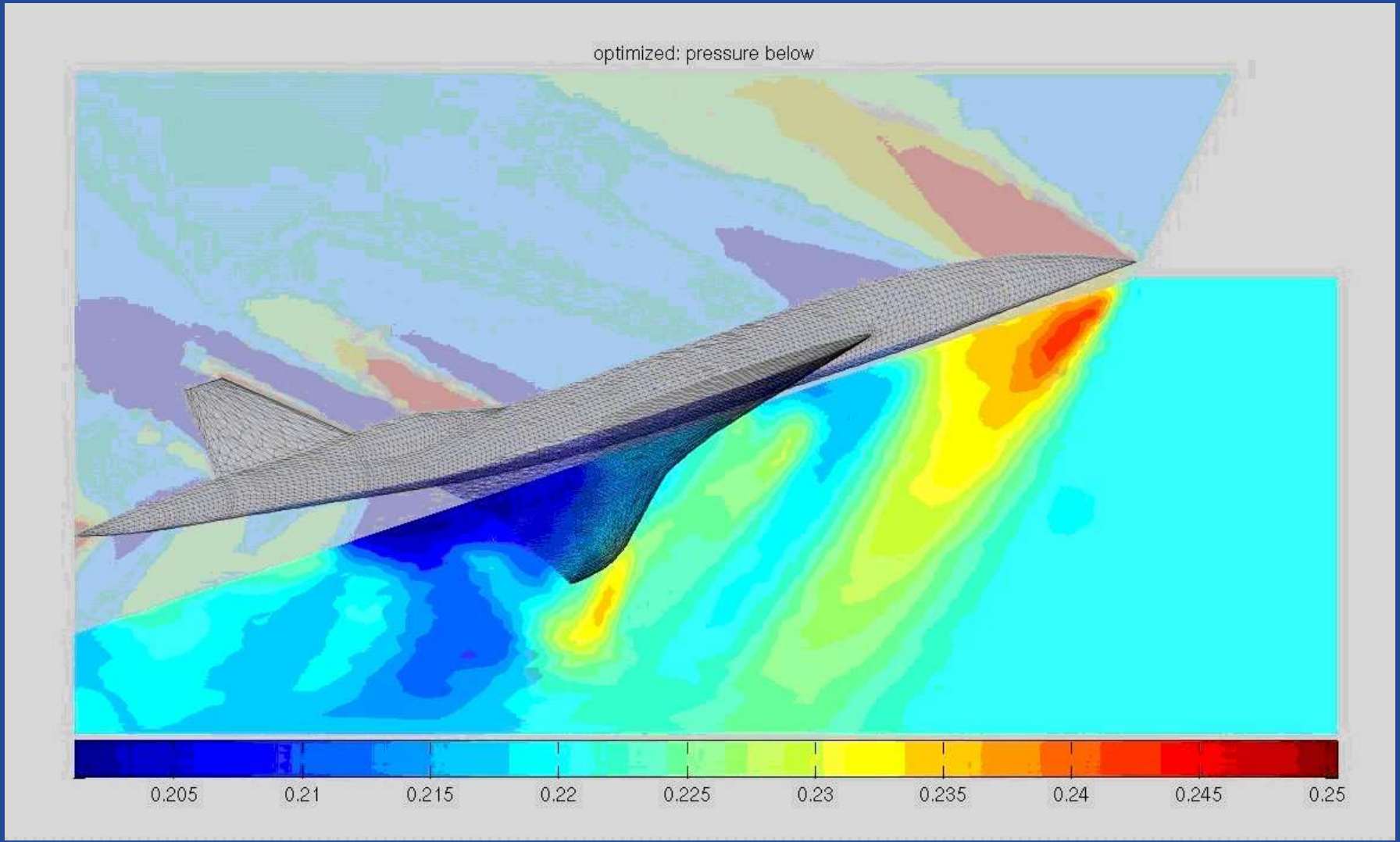
AIRFOIL OPTIMIZATION

3D WING PROFILE OPTIMISATION



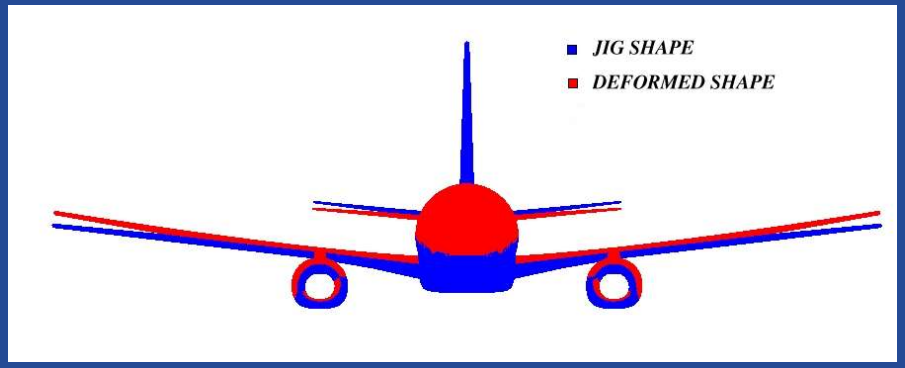
ONERA M6 SUPERSONIC WING
AOA = 3°, MACH 1.8

SUPERSONIC 3D OPTIMIZATION

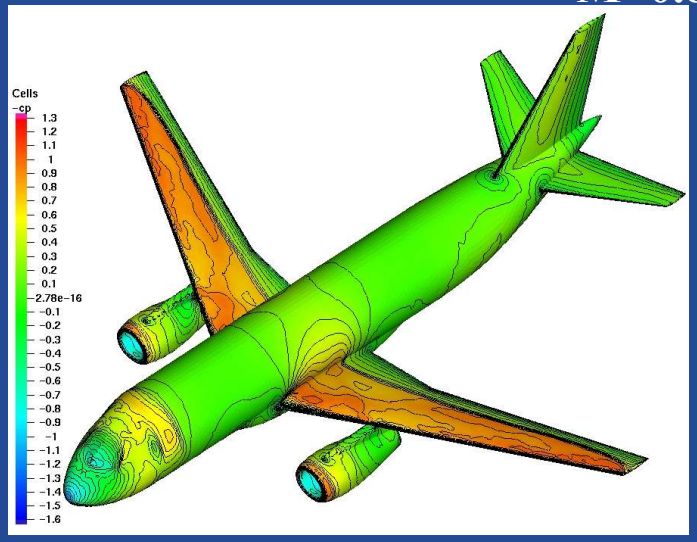


Aeroelastic Simulation: M=0.8, Nz=1, Z=11277 m

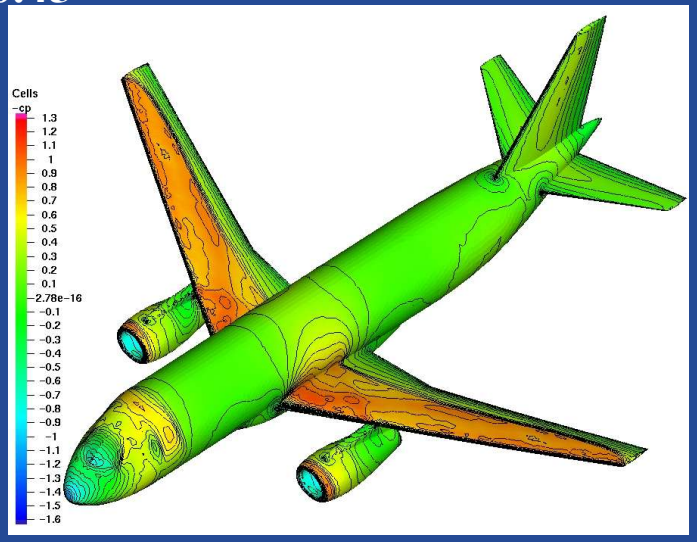
Alenia Aeronautica SMJ Configuration



M=0.8 , Cl=0.45



Jig Shape



Deformed Shape

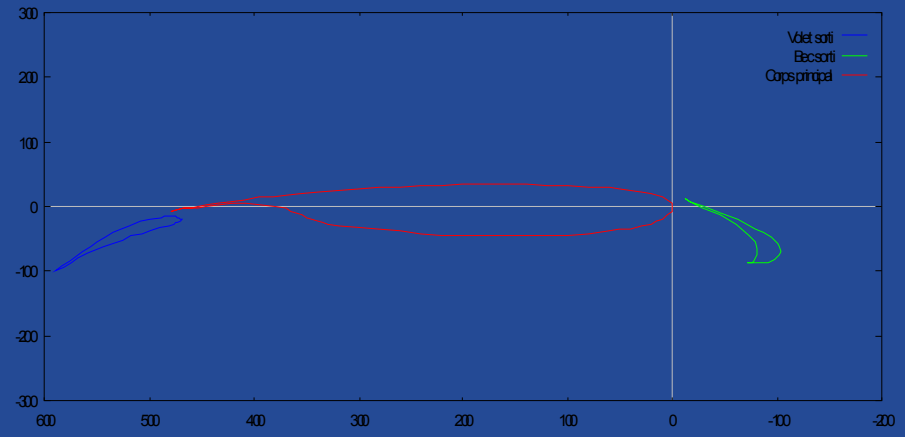
Alenia
AERONAUTICA

MULTIDISCIPLINE APPLICATIONS

AERONAUTICS

- COLLABORATIVE DESIGN
- SAFER
- QUIETER
- FUEL EFFICIENT
- ENVIRONMENT FRIENDLY
- REDUCED DESIGN TO MARKET TIME
- PRODUCT LIFECYCLE MANAGEMENT

MULTIDISCIPLINARY APPLICATIONS



AERODYNAMICS & ACOUSTICS

MULTIDISCIPLINE APPLICATIONS

AERO-ACOUSTICS

- **WIND MILL DESIGN: noise reduction**
- **HIGH SOCIETAL IMPACT**

MULTIDISCIPLINE APPLICATIONS

AERONAUTICS, TELECOMMUNICATIONS, ...

- DIGITAL AIRCRAFT
- VIRTUAL (FLIGHT) TESTS
- EXTENSIVE USE OF SIMULATION
- OPTIMIZED EARLY DESIGN DECISIONS
- INCREASING USE OPTIMIZATION
- ACCURACY MULTIDISCIPLINE OPTIMIZATIONS
- VERIFICATION & VALIDATION SIMU. & OPTIMI.

MULTIDISCIPLINE APPLICATIONS

AERONAUTICS

- AERODYNAMICS (CFD, L/D efficiency…)
- AERO-ELASTICITY (CSM, weigth reduction)
- VIBRO-ACOUSTICS (Sonic boom & cabin noise reduction)
- ELECTROMAGNETICS (RCS reduction)
- AERO-COMBUSTION (SFC, engine emissions)
- FLOW-CONTROL (vortex generators)
- FLIGHT MECHANICS COUPLING (flight dynamics)

CHALLENGES

- 3D SIMULATION & OPTIMIZATION
- VIRTUAL FLIGHT TESTS
- MULTIDISCIPLINARY DESIGN
- DESIGN VERIFICATION & VALIDATION

THE CHALLENGE

AERONAUTICS

- **MULTIDISCIPLINE SIMULATION & OPTIMIZATION**

ALSO AUTOMOTIVE, TELECOMMUNICATIONS, …

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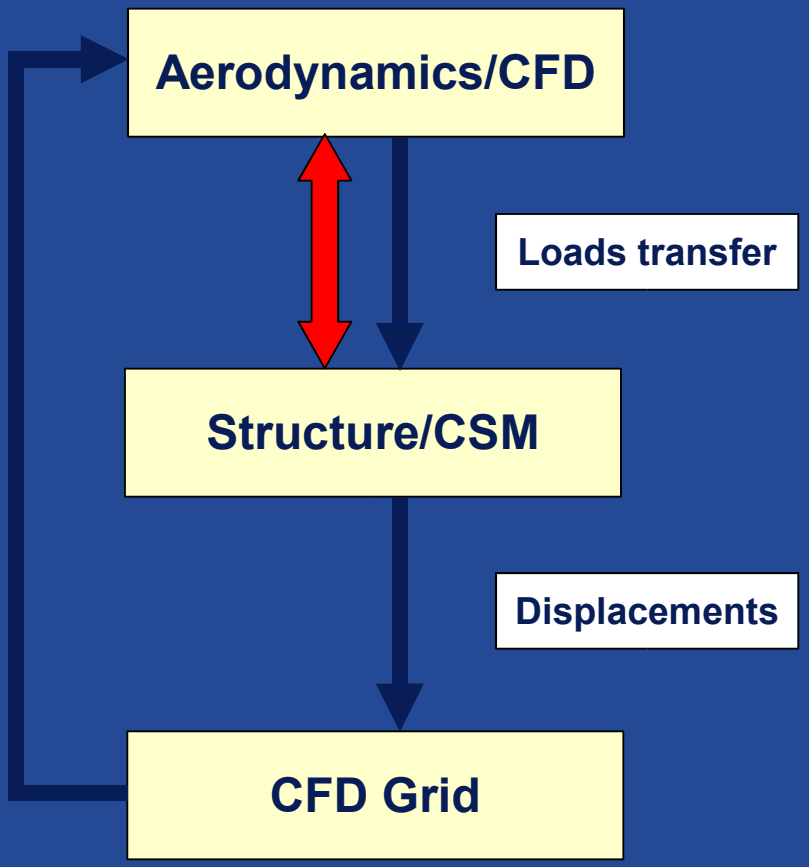
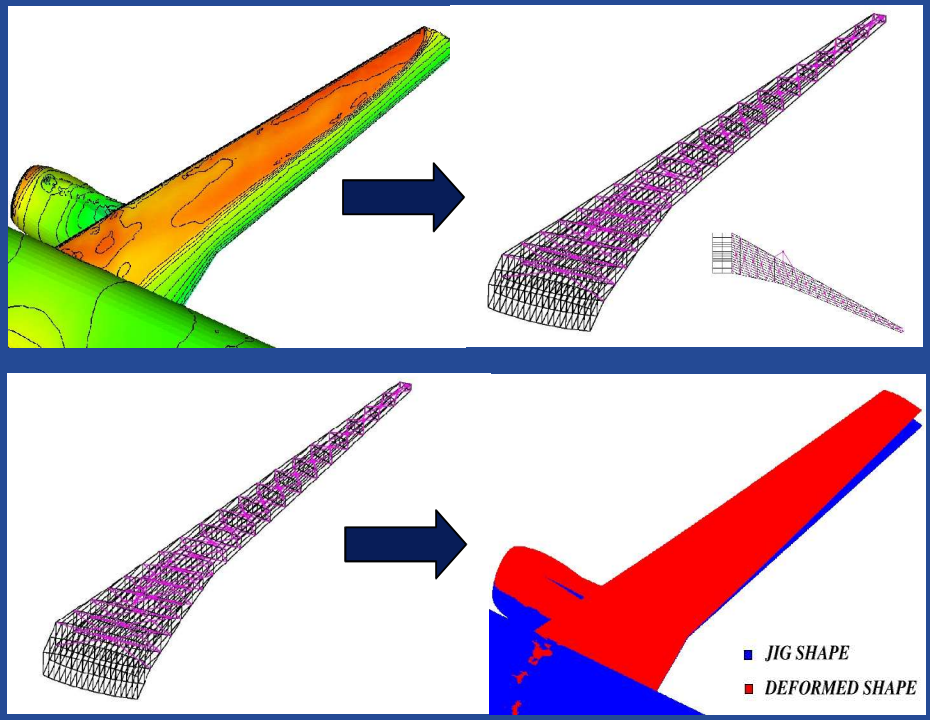
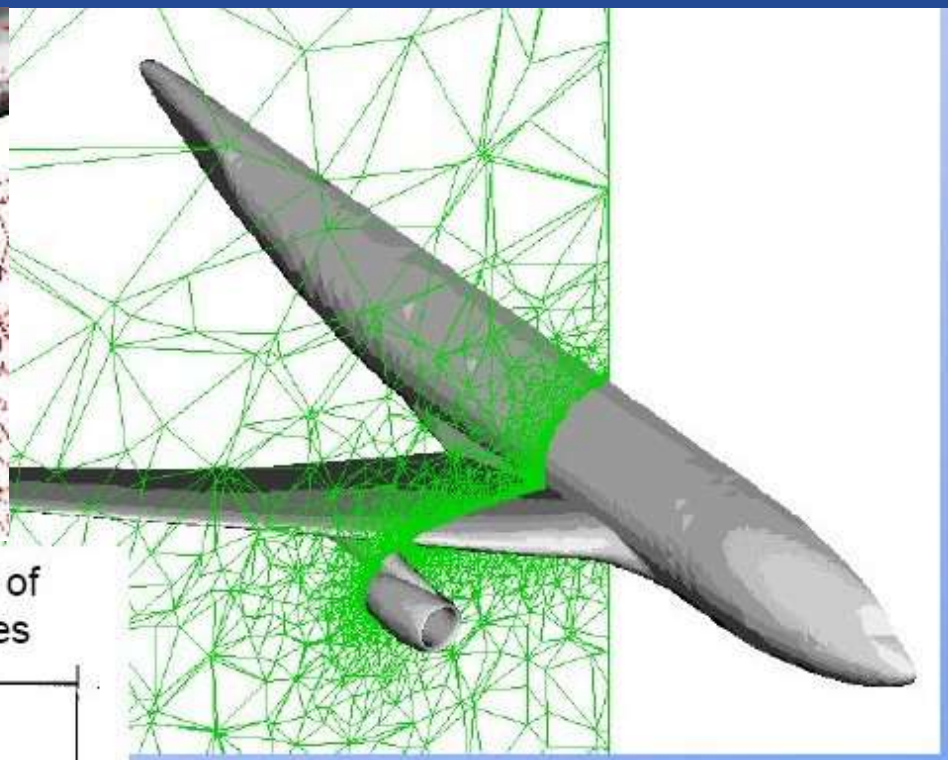
AERONAUTICA

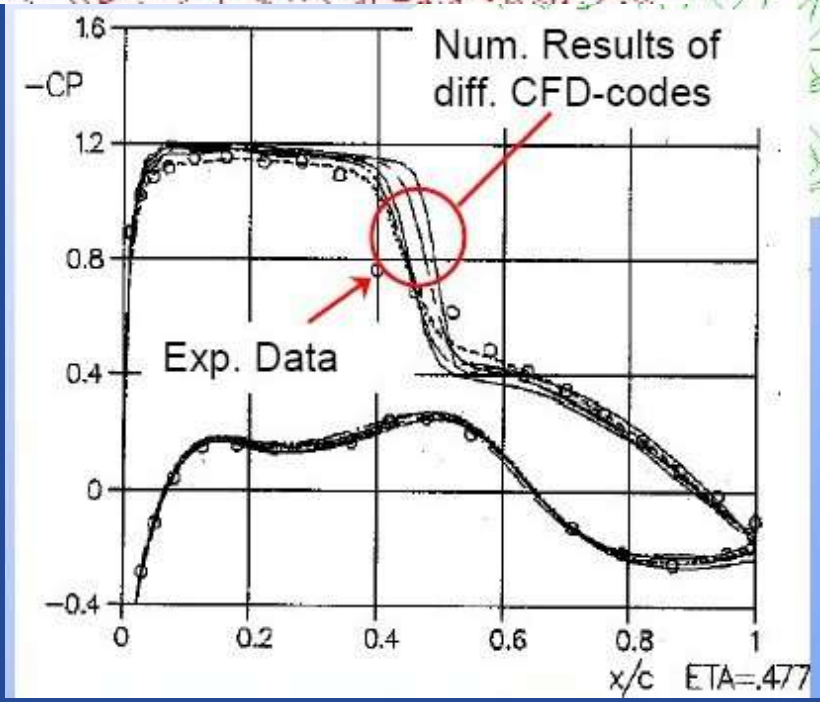
Fluid Structure Interaction: Process Overview

Aero-structural Design Process









Experiments are used for validation purposes, but:

Aeroelastic deformation during wind tunnel tests is unknown:

Aeroelasticity
Multi-disciplinary applications

FACING THE CHALLENGE

AERONAUTICS, TELECOM, …

USE INNOVATIVE COMPUTATIONAL METHODS !

FACING THE CHALLENGE

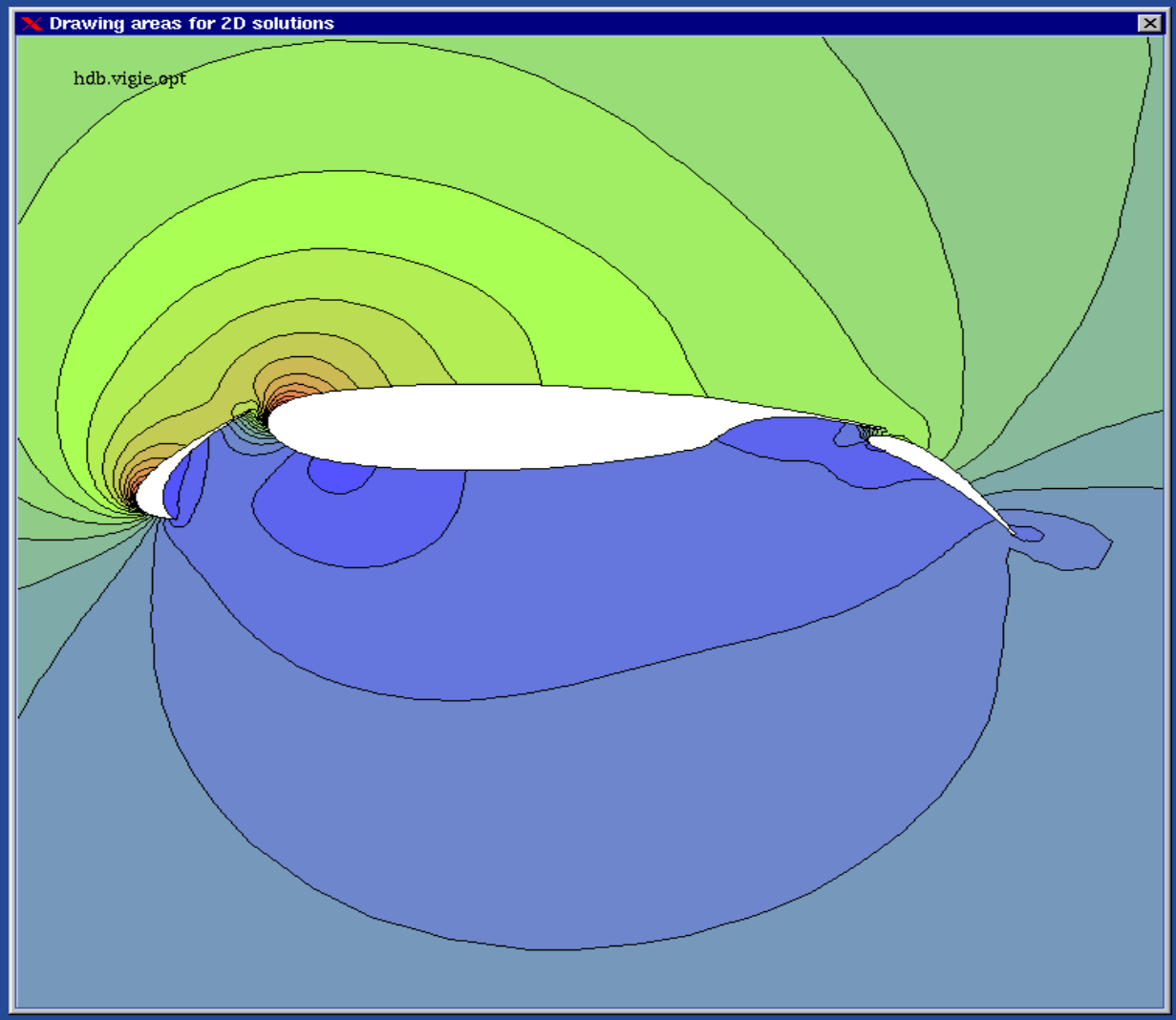
BASED ON EVOLUTIONARY APPROACHES

GAME THEORY, GENETIC ALGORITHMS, …
FREE FORM DEFORMATION, …
MULTI-SCALE, HIERARCHIC OPTIMIZATION, …
DOMAIN DECOMPOSITION, …

WELL SUITED TO RUN ON THE GRID !

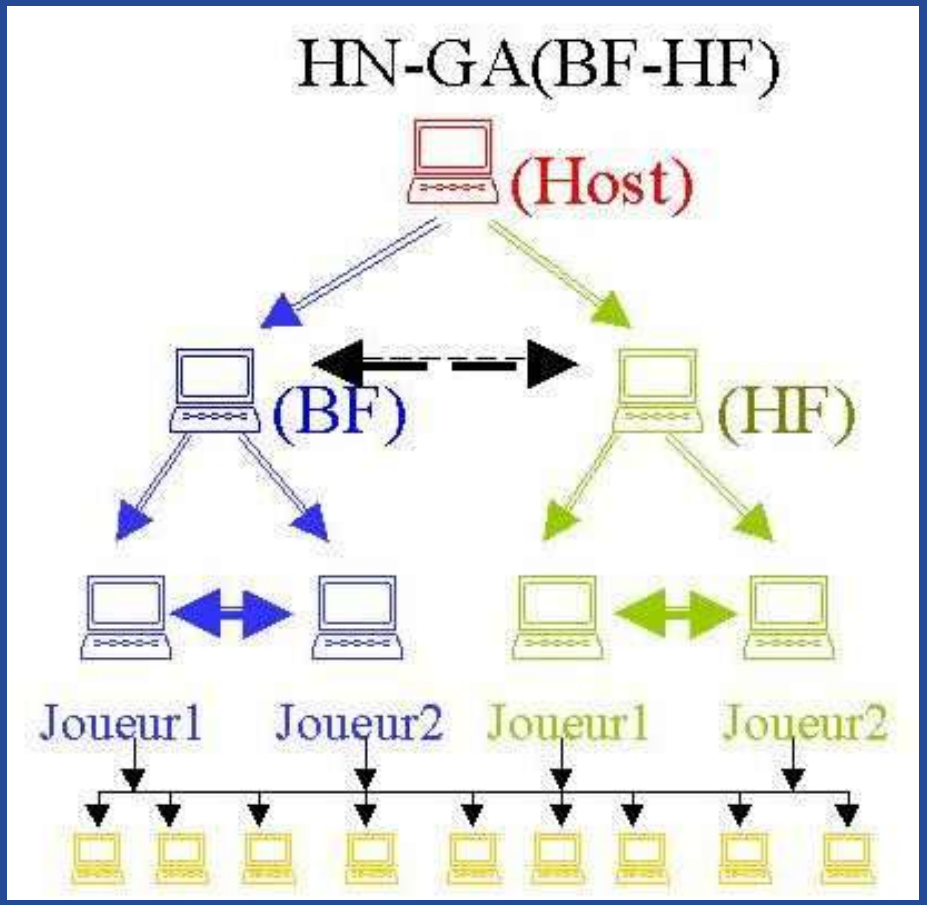
ROBUST, PARALLEL, …

MULTI-PLAYER AIRFOIL OPTIMIZATION



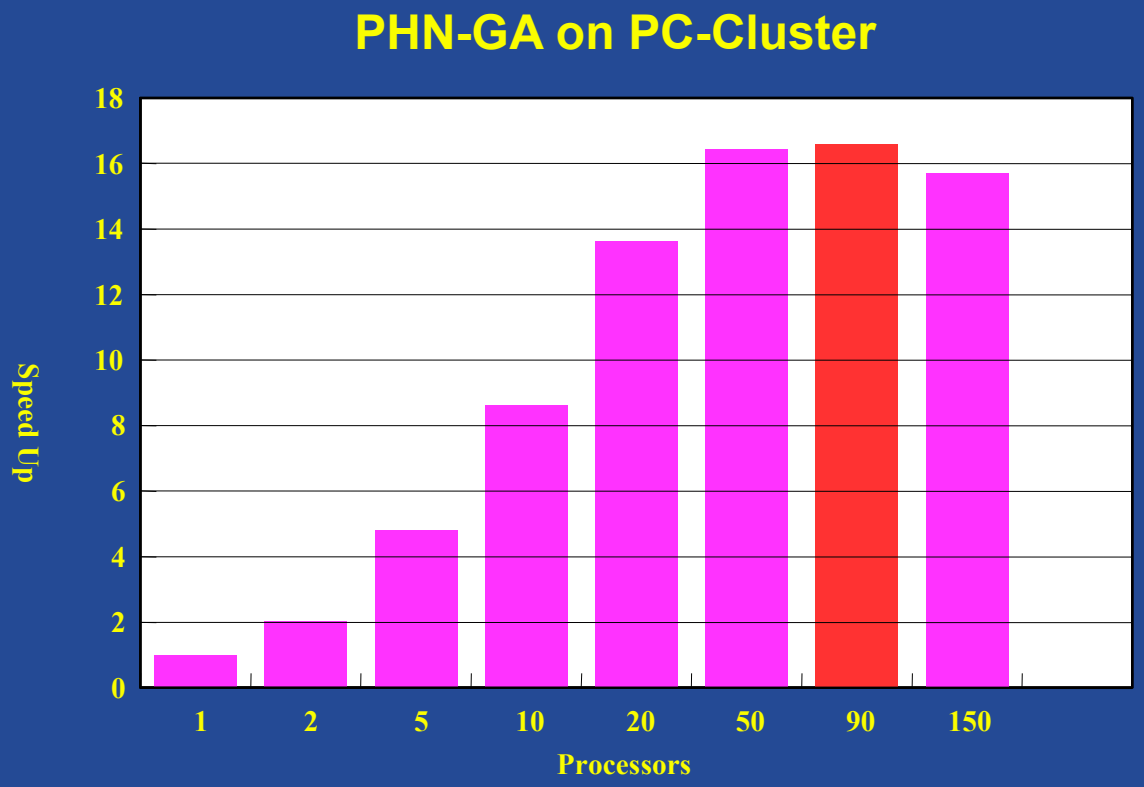
APPLICATION EXAMPLE

OPTIMISATION STRATEGY



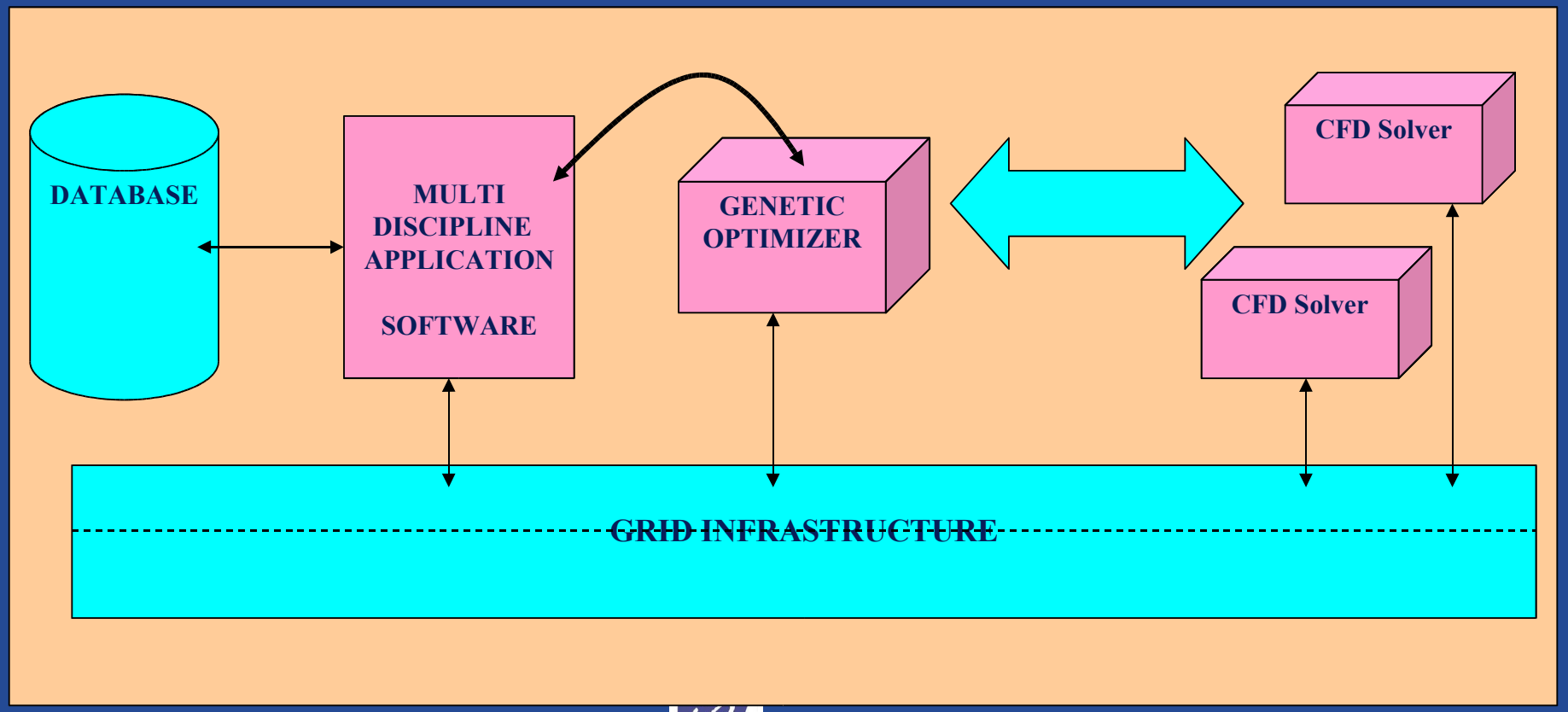
APPLICATION EXAMPLE

PERFORMANCE DATA

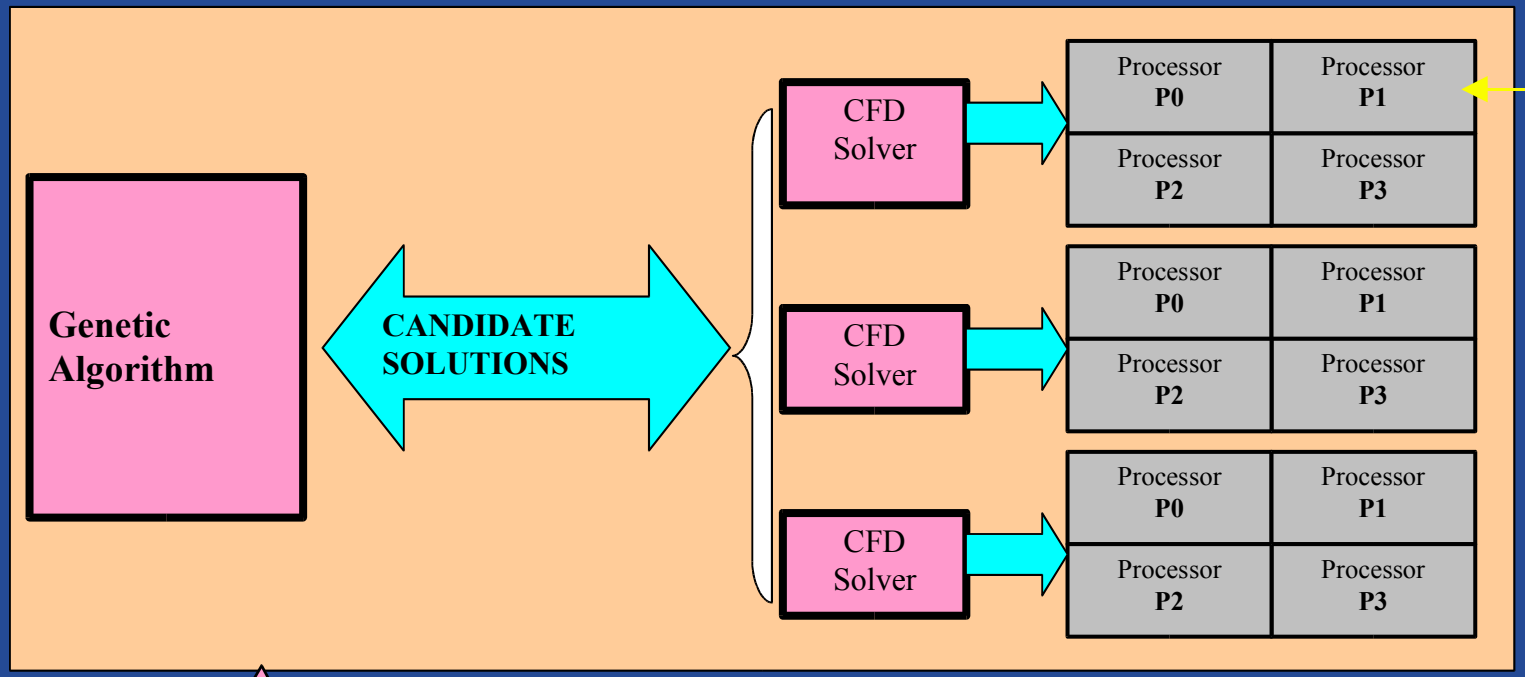


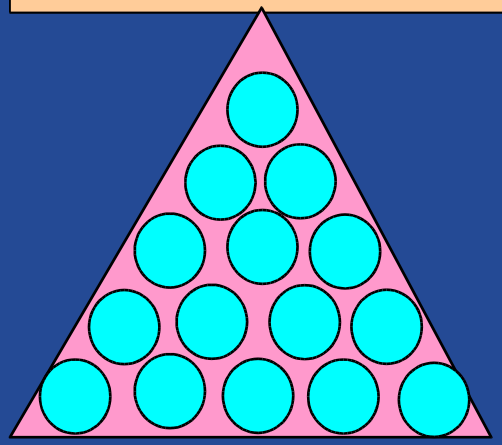
DISTRIBUTED INTEGRATION PLATFORM

GRID COMPUTING



NESTED LEVELS of PARALLELISM

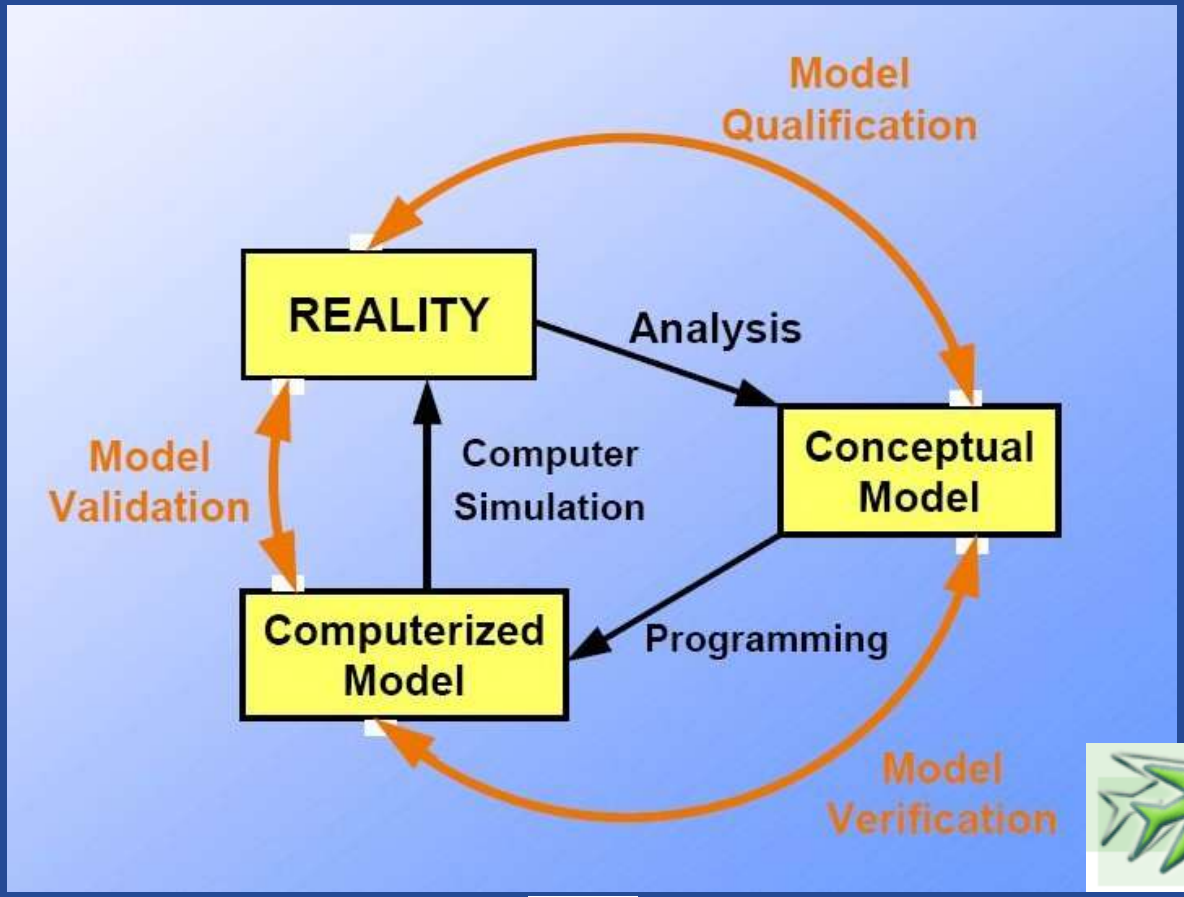




Genetic algorithm based on selection, mutation, crossover

VERIFICATION & VALIDATION

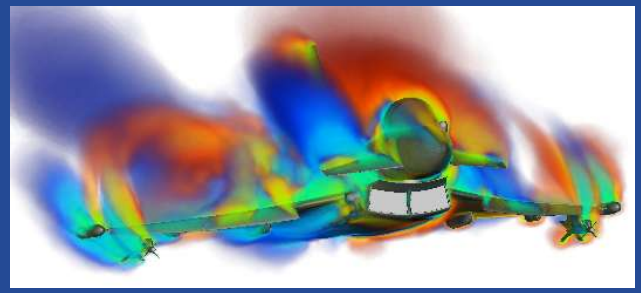
CHALLENGE ADVANCED NUMERICAL METHODS



Promuval

V&V

Promuval



- The integration of existing (verified and validated) tools/software must be supported
  - ⇨ different programming languages
  - ⇨ flexible interfaces
- Web-based support of an experts knowledge data base
  - ⇨ by forums, newsgroups, experts data base, V&V data base,….
  - ⇨ ‘attractive room’ to bring single discipline parties close together

V&V

- Definition of effective and flexible interface structures in an early project phase
  ⇨ strong impact on success of a GRID integration platform
- General: High speed LAN and WAN for process communication data transfer required
  but CFD simulations for complex configurations also require efficient libraries (e.g. MPI) for distributed parallel systems (e.g. PC-cluster, grids), also.
- Complexity and flexibility of the GRID integration platform:
  great flexibility in linkage of a lot of different tools and software required
  ⇨ to reduce the development risk a step by step approached could be helpful
- A high level of data security must be ensured in an early stage of the project otherwise only trivial tasks will be tested and worked out on such a platform by industrial partners

GRID COMPUTING

- HIGH PERFORMANCE COMPUTING
- HIGH THROUGHPUT COMPUTING
- PETA-DATA MANAGEMENT
- LONG DURATION APPLICATIONS

GOAL

- CROSS-FERTILIZATION of
- HIGH PERFORMANCE COMPUTING and
- ADVANCED COMPUTATIONAL METHODS for
- MULTIDISCIPLINARY SIMULATION & OPTIMIZATION
- USING GRID TECHNOLOGY
- TO SOLVE MULTIDISCIPLINARY DESIGN

CROSS-LEVERAGE

GRIDS & INNOVATIVE COMPUTATIONAL METHODS

- **NESTING SEVERAL LEVELS PARALLELISM**
- **EVOLUTIONARY METHODS (GAME THEORY, …)**
- **DOMAIN DECOMPOSITION METHODS**
- **MULTIPLE CODE INSTANCES ON PC-CLUSTERS**
- **PARALLEL EXECUTION MULTIDISCIPLINE CODES**
- **PARALLEL PROGRAMMING**

GRID COMPUTING ENVIRONMENTS

ADVANCED FEATURES

- HIGH-PERFORMANCE & TRANSPARENT DISTRIBUTION
- USING CURRENT COMMUNICATION STANDARDS
- USING CURRENT PROGRAMMING STANDARDS
- WEB SERVICE USER INTERFACES
- OPTIMIZED LOAD BALANCING & COMMUNICATION FLOWS

COUPLING w ONGOING EFFORTS

- Performance monitoring : dynamic load balancing
- Virtual organisations : security, authentication, authorisa.
- Service oriented architectures
- Integrating applications with grid computing technology
- Enabling applications technologies
- Standards : OGSA, Web & Grid Services, GT4, …

CONCLUSION

- **MULTIDISCIPLINARY DESIGN ENVIRONMENTS**

  OPTIMAL DESIGN IN COLLABORATIVE ENVIRONMENTS

- **« COTS » + Gb/sec NETWORKS + WEB & GRID services**

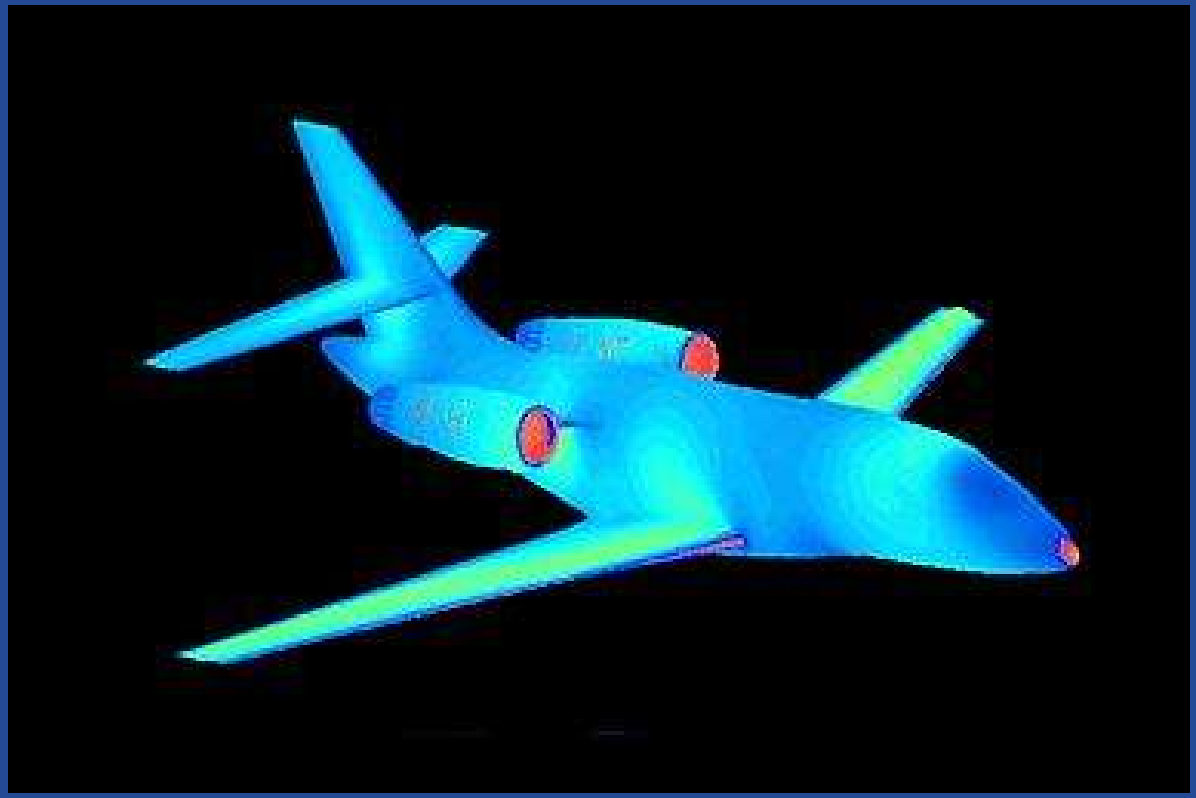
  FLEXIBLE & INTEROPERABLE APPS DEVELOPMENT

- **SIMULATION & OPTIMIZATION ENVIRONMENTS**

  REAL CSCW ON FULL SCALE DIGITAL MOCKUPS

CONCLUSION

CROSS-FERTILIZING INNOVATIVE NUMERICAL METHODS & GRID TECHNOLOGY



LARGE COLLABORATIVE ENVIRONMENTS

« VIRTUAL FLIGHT TESTS FOR DIGITAL DYNAMIC AIRCRAFT »

REFERENCES

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