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Welcome to the World of Fast Morphing!

ESSS

RBF Morph software

How to reshape the CAE workflows by Radial Basis Functions mesh morphing

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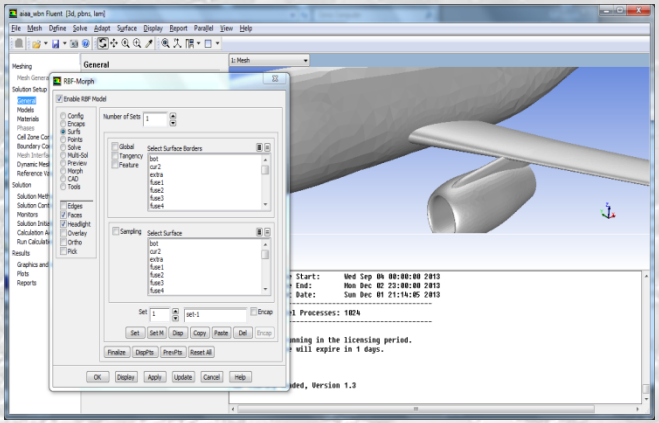
Outline

- Company Introduction
- RBF Morph Software Line
- Ongoing Researches
- Industrial Applications

Company Introduction

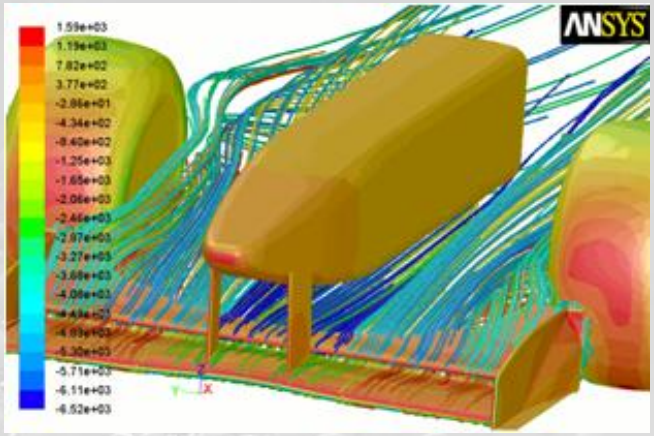
RBF Morph is a pioneer and world-leading provider of numerical morphing techniques and solutions conceived to efficiently handle **shape optimization studies** concerning most challenging industrial applications. We are an independent software-house and vendor. Our main product is RBF Morph™, that is a unique morpher that combines a very **accurate control** of the geometrical parameters with an extremely **fast mesh smoothing** properly designed to be integrated in advanced computational optimization procedures.

The RBF Morph tool is currently available in the market mainly as add-on of the CFD commercial code ANSYS® Fluent®.



Company Introduction

The RBF Morph tool had its inception in 2008 as on-demand solution for a **Formula 1** top team. The need was a novel technology able to change the shape of large CFD numerical models **as fast as possible**. The final result had been so good that the technology was packaged in a commercial software product and launched onto the market.



At present, Dr. Marco Evangelos Biancolini is the unique owner of the RBF Morph technology and, as Director, avails himself of the collaboration of several experts for the deliver of products and services.

Company Introduction

- Morphing-based numerical tools and services
- RBF Morph Milestones
  - ✓ 2008: tool implementation for Formula 1 top team consultancy activity
  - ✓ 2009: founded in Italy
  - ✓ 2009: Software Partner of ANSYS
  - ✓ 2009: at EASC **RBF Morph** won the *Most Advanced Approach Award Most Innovative Approach using Simulation Methods*
  - ✓ 2011: strategic partnership with Tor Vergata University (Rome)
  - ✓ 2012: OEM partner of ANSYS
  - ✓ 2013: beneficiary of an FP7 AAT Project RBF4AERO
  - ✓ 2013: at ASWC **RBF Morph** awarded for the *Best use of HPC*
  - ✓ 2013: Partner of Enginsoft
  - ✓ 2014: beneficiary of FP7 Project RIBES
  - ✓ 2014: beneficiary of FPT Fortissimo

ANSYS®

ENGIN SOFT

easc
EUROPEAN AUTOMOTIVE SIMULATION CONFERENCE

2013 Automotive Simulation World Congress

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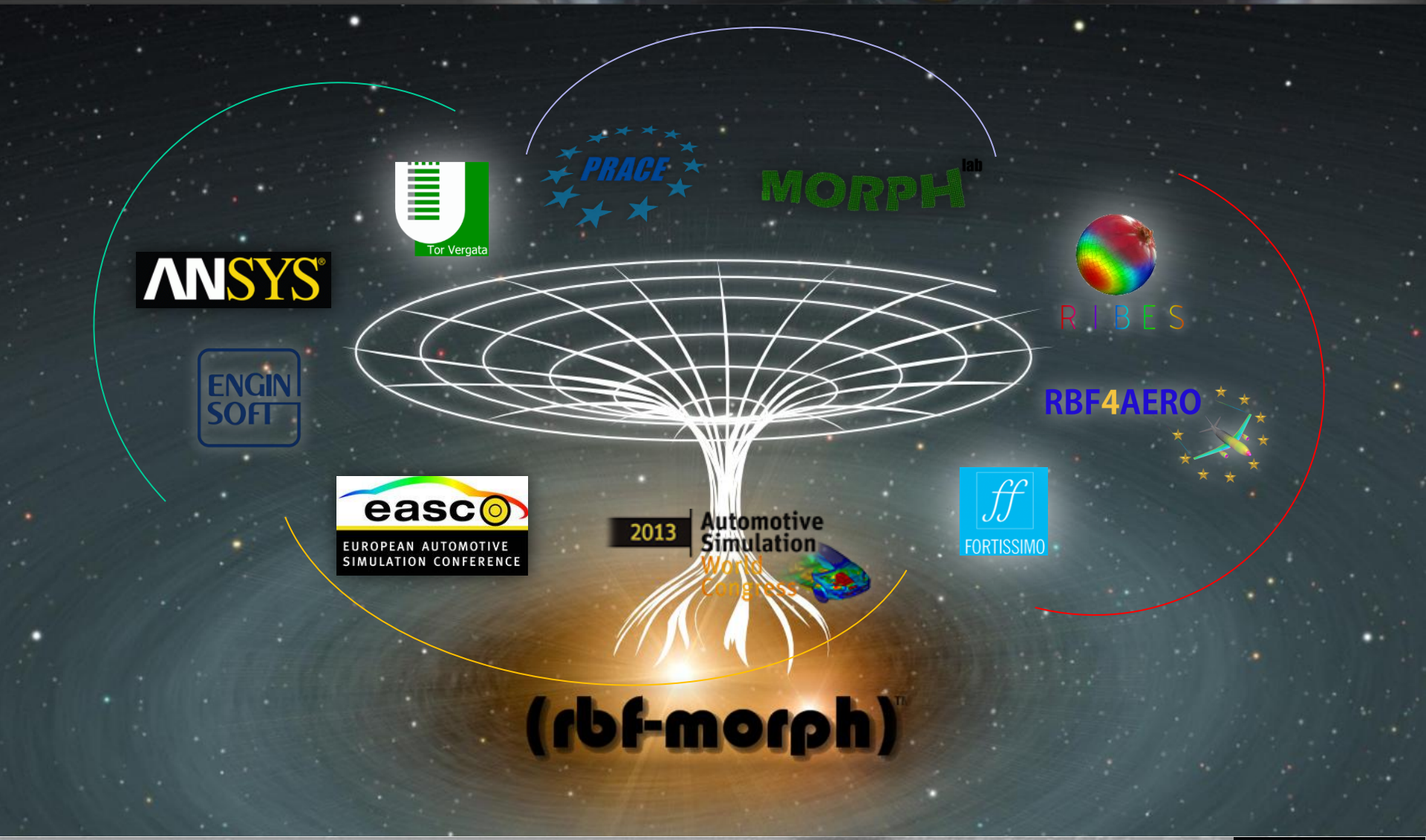
Knowledge Galaxy

ESSS



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ANSYS

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RBF Morph, an ANSYS Inc. Partner

RBF Morph software line

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RBF Morph software line

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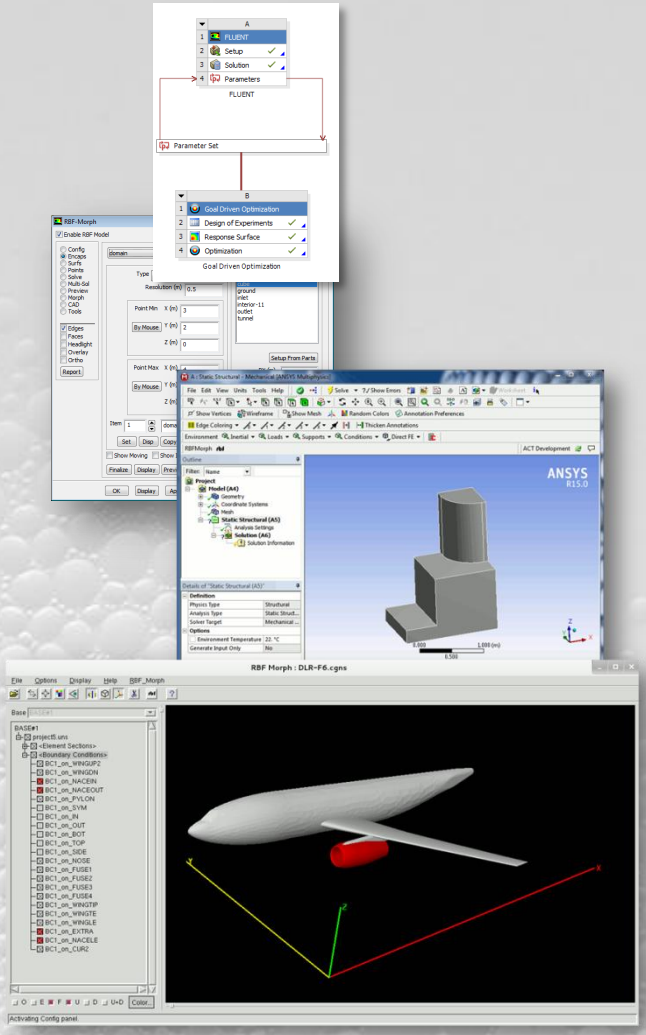
- Awarded mesh morphing software available as an add-on for **ANSYS Fluent** CFD solver
- HPC RBF **general purposes** library (state of the art algorithms, parallel, GPU)
- Stand alone morphing software + smoothing commands for different mesh formats
- ANSYS Mechanical **ACT module** (first release planned in June 2014)



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RBF Morph Fluent add-on

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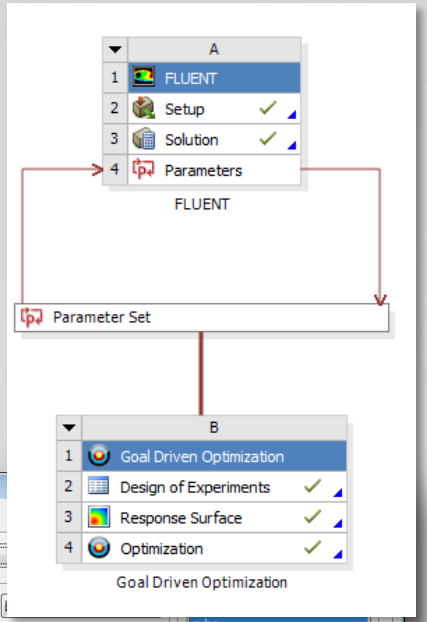
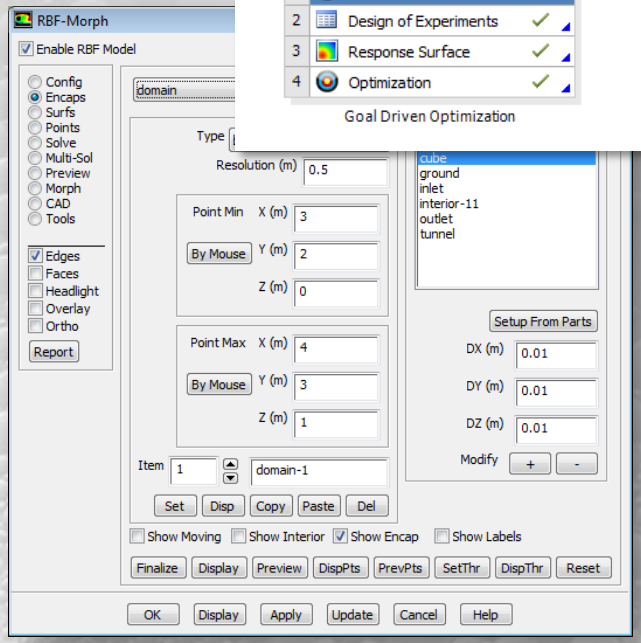
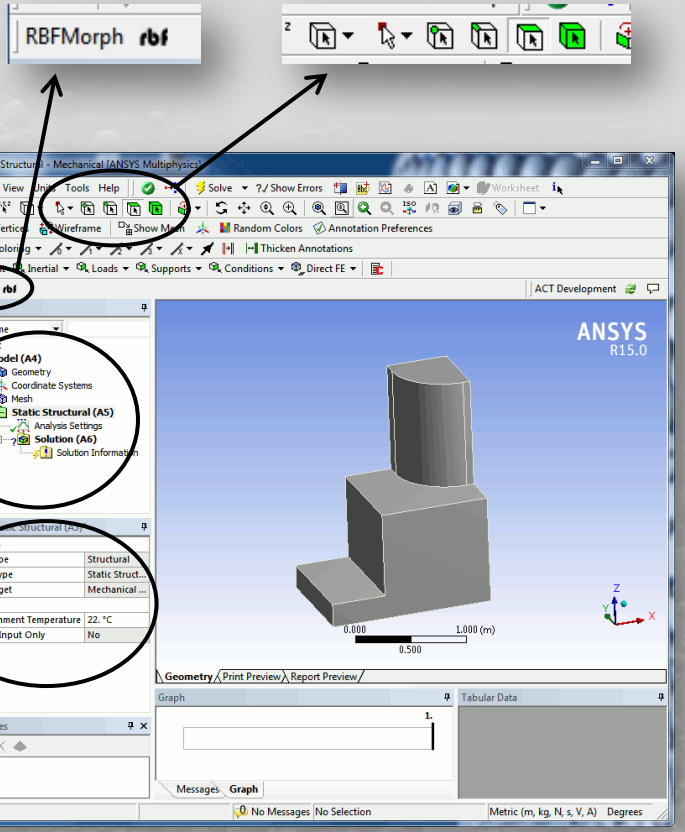
- **Add on** fully integrated within **Fluent** (GUI, TUI & solving stage), **Workbench** and **Adjoint Solver**
- **Mesh-independent** RBF fit used for surface mesh morphing and volume mesh smoothing
- **Parallel** calculation allows to morph **large size** models (many millions of cells) in a short time
- Management of **every kind of mesh** element type (tetrahedral, hexahedral, polyhedral, etc.)
- Support of the **CAD re-design** of the morphed surfaces
- **Multi fit** makes the Fluent case truly parametric (only 1 mesh is stored)
- **Precision**: exact nodal movement and exact feature preservation (**RBF** are better than **FFD**)

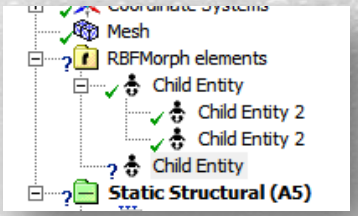


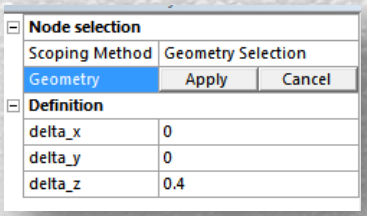


RBF Morph ACT module for mechanical

- Deeply integrated in ANSYS Mechanical: same look & feel, same interaction logic
- Nested in the usual Mechanical tree as an added object, shares its scoping tools for **geometrical** and **mesh elements** selections
- Written in **python** and **xml**, uses external RBF Morph core libraries
- Child **hierarchical logic** for complex morphings (two steps, three steps, …, n steps setups)

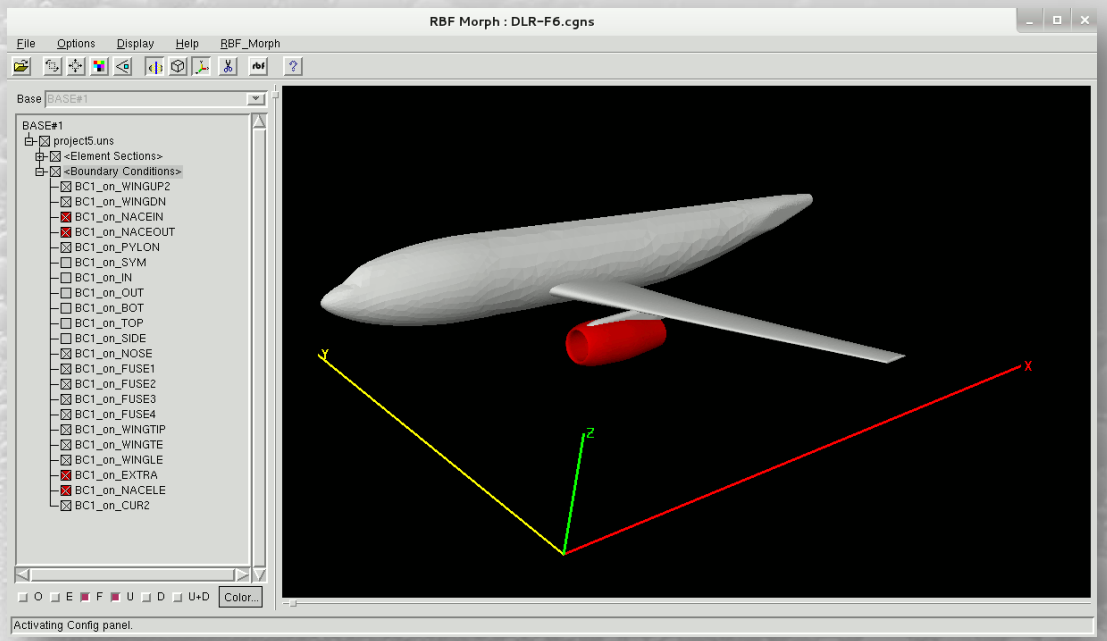






RBF Morph Stand Alone

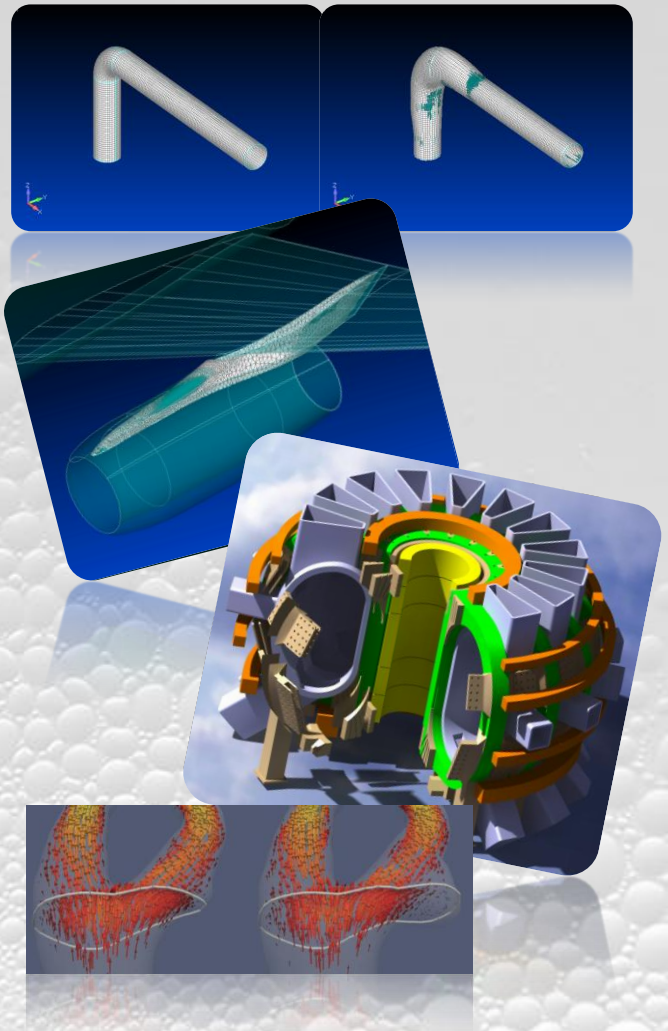
- RBF solutions are fully compatible and **exchangeable** between add-on and standalone versions
- Support for STL and CGNS file formats. Selected morphed surfaces can be exported in STL format and **back to CAD** is possible via STEP files
- **Add-on-like** interface
- **Solver independent** process currently supports many mesh formats
- Functions **scriptable** via tcl
- Global supported bi-harmonic functions and C^0, C^2, C^4 compact supported functions available



Ongoing RBF Morph Researches

Ongoing RBF researches

- RBF Morph and Adjoint coupling: Adjoint sculpting, Adjoint preview, Augmented DOE
- **STL** targeting, **CAD** controlled surfaces
- **Mesh to CAD** features
- Mapping of **magnetic** and **pressure** loads
- Interpolation of **hemodynamic** flow fields acquired *in vivo*
- Strain and **stress calculation** (experimental data, coarse FEM, isostatic lines)



RBF4AERO EU Project

- "Innovative Benchmark Technology for Aircraft Engineering Design and Efficient Design Phase Optimisation" –

ACP3-GA-2013-605396

- **www.rbf4aero.eu**

RBF4AERO

D'APPOLONIA
consulting, design, operation & maintenance engineering

Tor Vergata

PIPISTREL

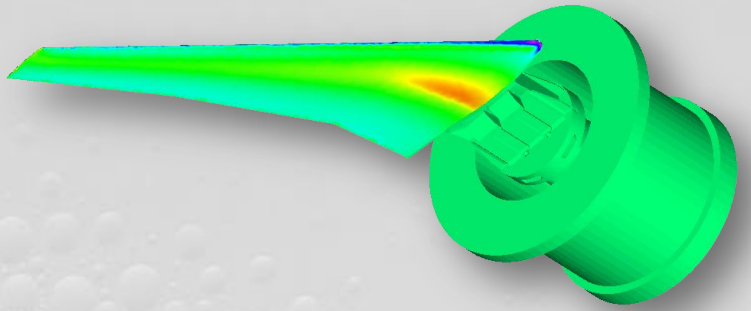
TEI

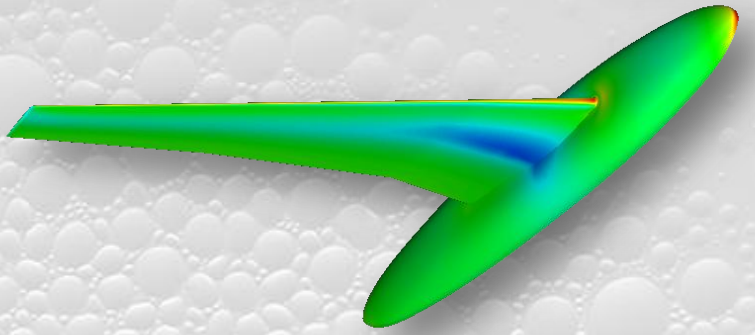
VON KARMAN INSTITUTE

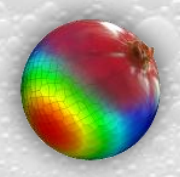
RIBES

- **R**adial basis functions at fluid **I**nterface **B**oundaries to **E**nvelope flow results for advanced **S**tructural analysis

JTI-CS-2013-GRA-01-052







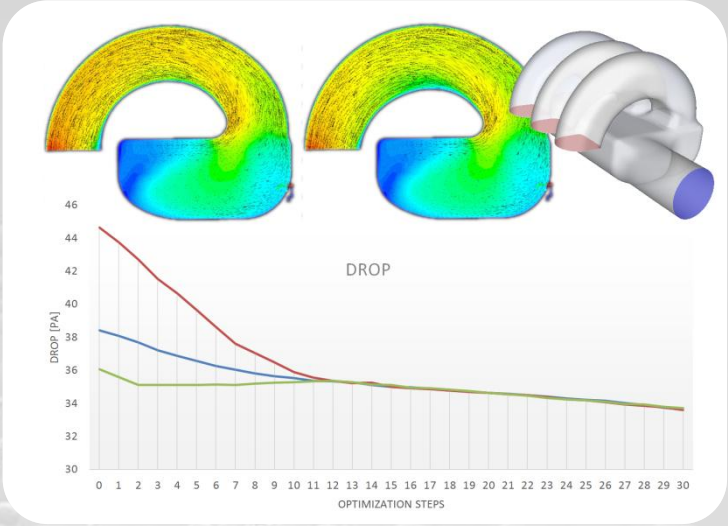
RIBES

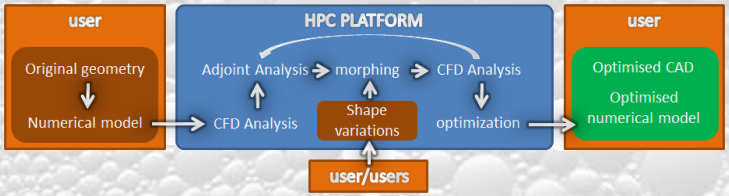
CLEANSKY

Tor Vergata

Fortissimo EU Project

- **F**actories **O**f the Future **R**esources, **T**echnology, **I**nfrastructure and **S**ervices for **SI**mulation and **MO**delling
- Approved experiment: “Virtual Automatic Rapid Prototyping Based on Fast Morphing on HPC Platforms”





FORTISSIMO

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CINECA SCAI
SuperComputing Applications and Innovation

Solver performances

- 10.000 RBF centers FIT
  - 120 minutes Jan 2008
  - 5 seconds Jan 2010
- Largest fit **2.600.000** 133 minutes
- Largest model morphed **300.000.000** cells
- Fit and Morph a **100.000.000** cells model using **500.000** RBF centers within **15 minutes**

#points	2010 (Minutes)	2008 (Minutes)
3.000	0 (1s)	15
10.000	0 (5s)	120
40.000	1 (44s)	Not registered
160.000	4	Not registered
650.000	22	Not registered
2.600.000	133	Not registered

Next stop: GPU acceleration!

NVIDIA CUDA

- Single RBF complete evaluation
- Unit random cube
- **GPU**: Kepler 20 2496 CUDA Cores
  GPU Clock 0.71 GHz
- **CPU**: quad core Intel(R) Xeon(R) CPU E5-2609 0 @ 2.40GHz

#points	CPU	GPU	speed up
5000	0,098402	0,004637	21,2
10000	0,319329	0,011746	27,2
15000	0,667639	0,024982	26,7
20000	1,135127	0,038352	29,6
25000	1,721781	0,054019	31,9
30000	2,451661	0,079459	30,9
35000	3,306897	0,108568	30,5
40000	4,286706	0,134978	31,8
45000	5,390029	0,181181	29,7
50000	6,707721	0,2135	31,4
100000	26,13633	0,745482	35,1
150000	58,96981	1,735367	34,0
200000	115,3628	2,861737	40,3

Industrial Applications

Formula 1 Front Wing

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Motorbike Windshield (Bricomoto, MRA)

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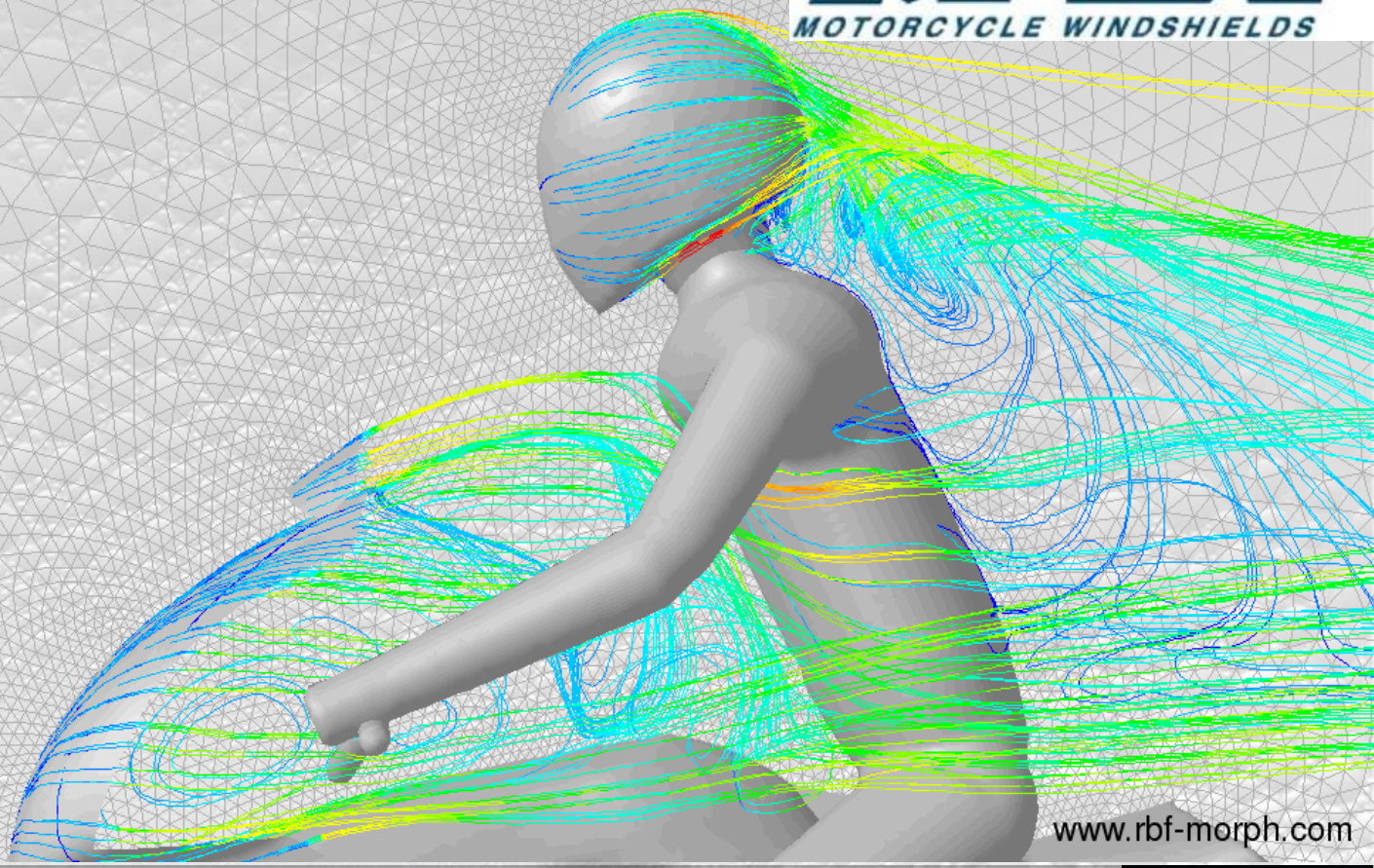
BRICO moto

MRA® MOTORCYCLE WINDSHIELDS



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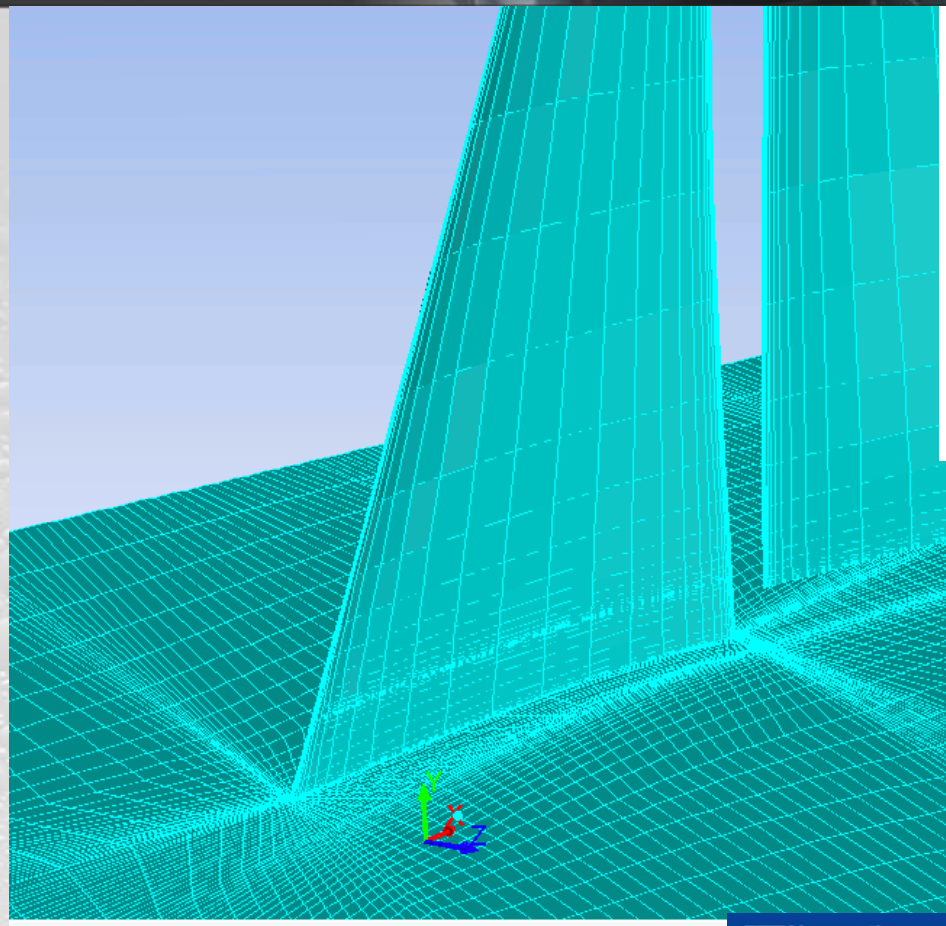
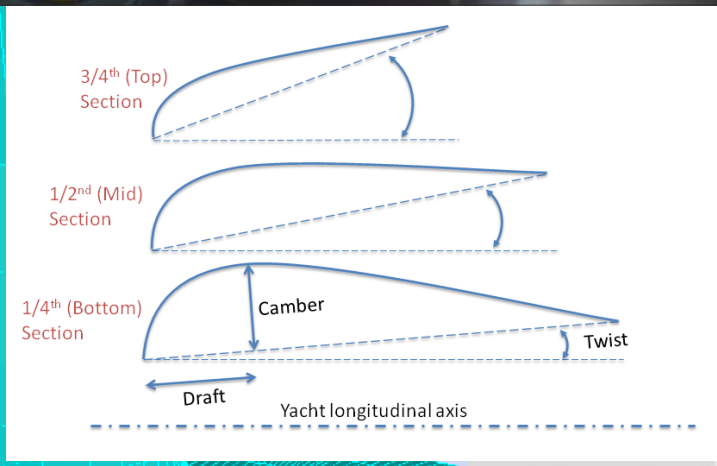
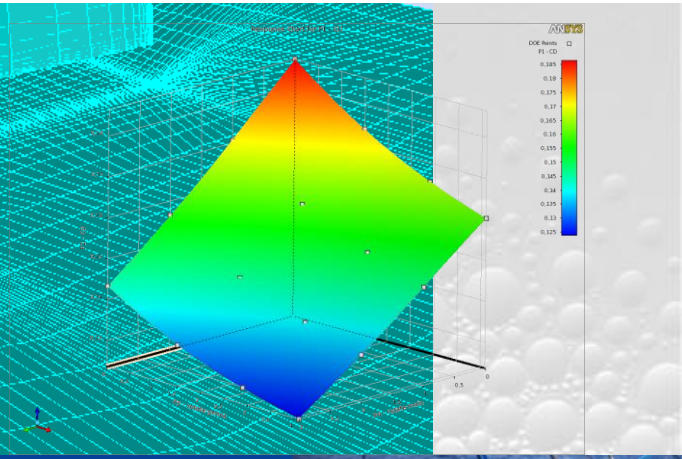
Sails Trim (Ignazio Maria Viola, University of Newcastle)







Morphing Preview (A=0)

Newcastle University
Yacht and superyacht consultancy and research
school of marine science and technology
ignazio.viola@ncl.ac.uk

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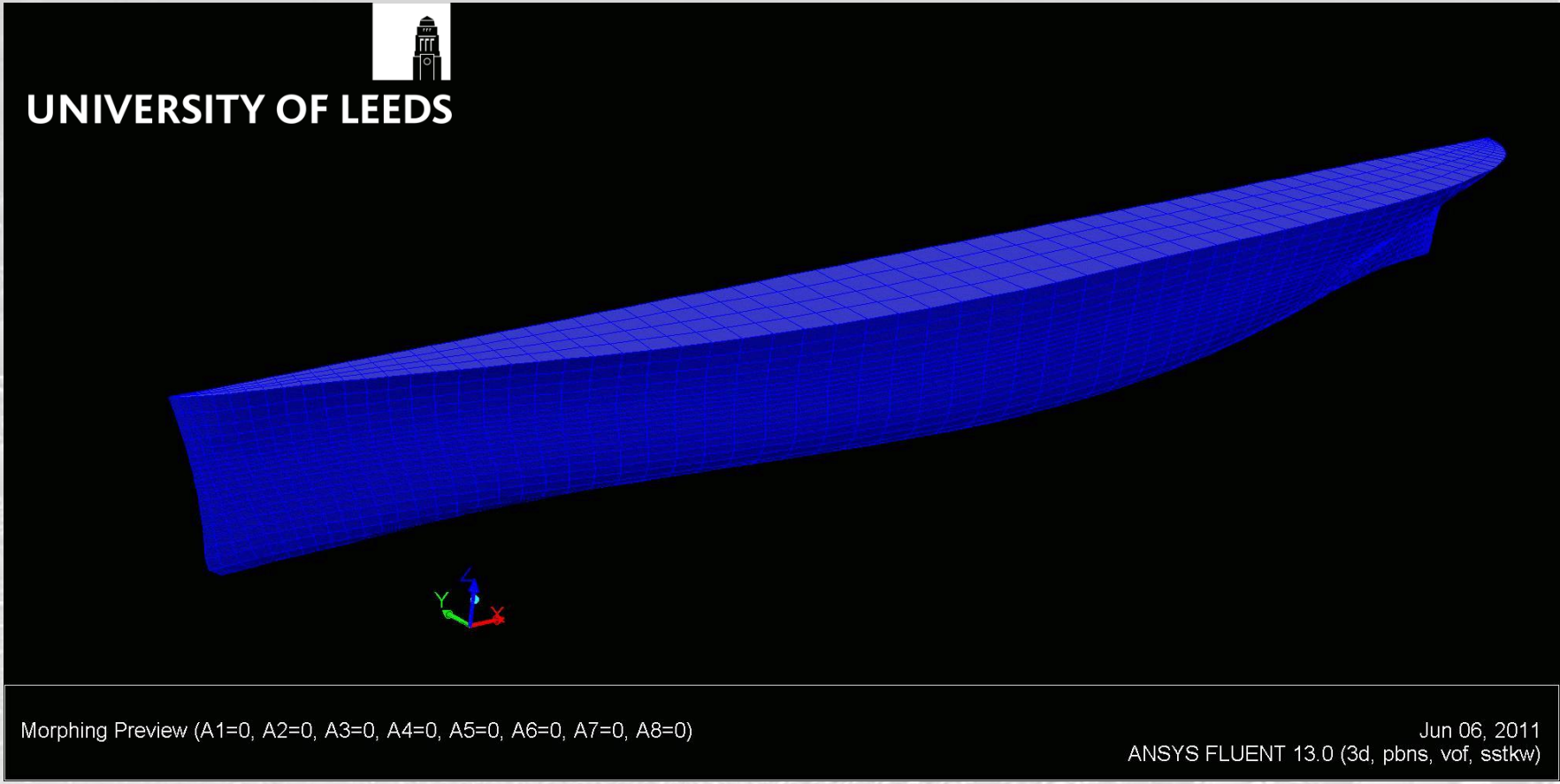
Ship Hull (University of Leeds)



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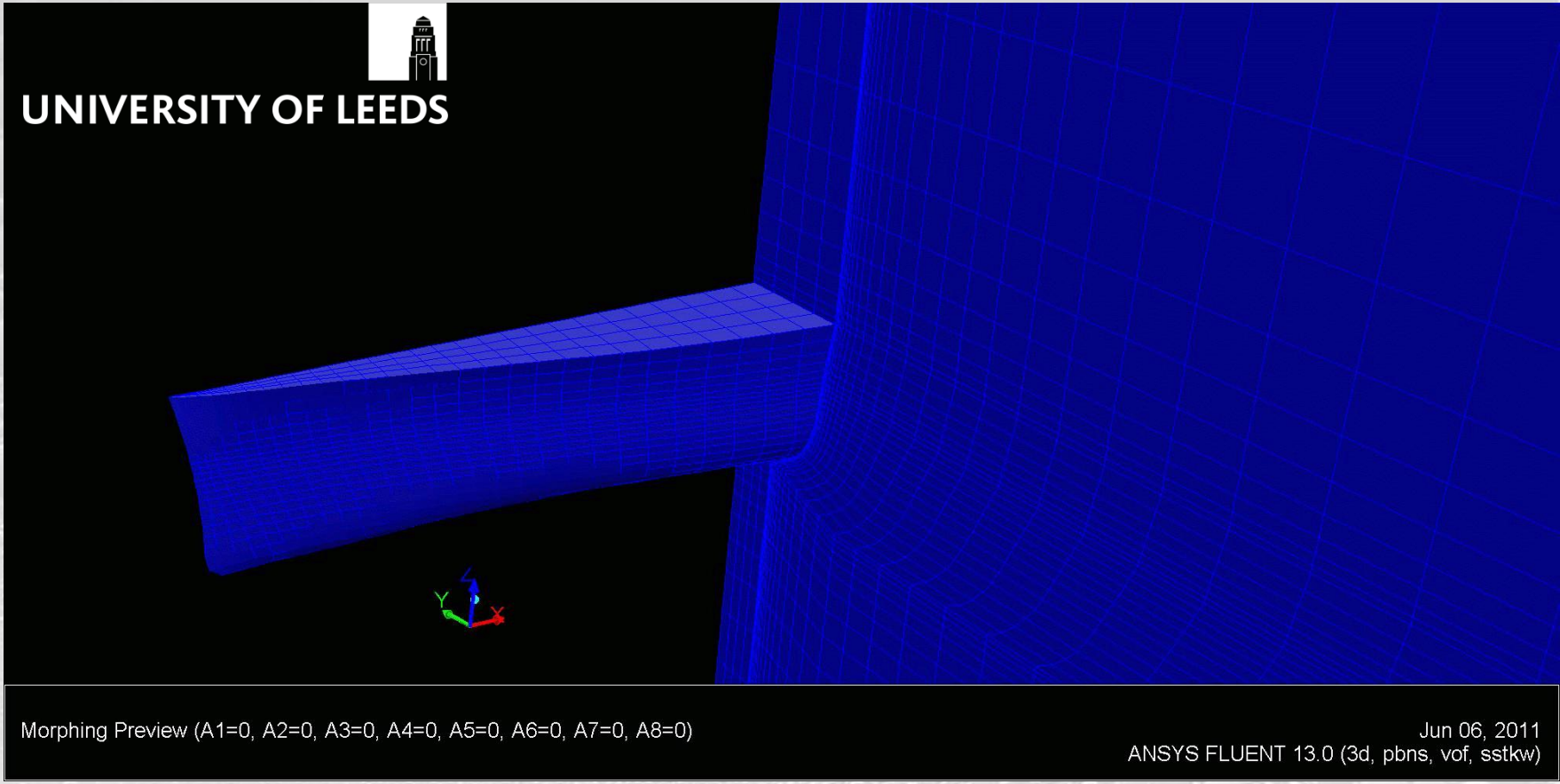

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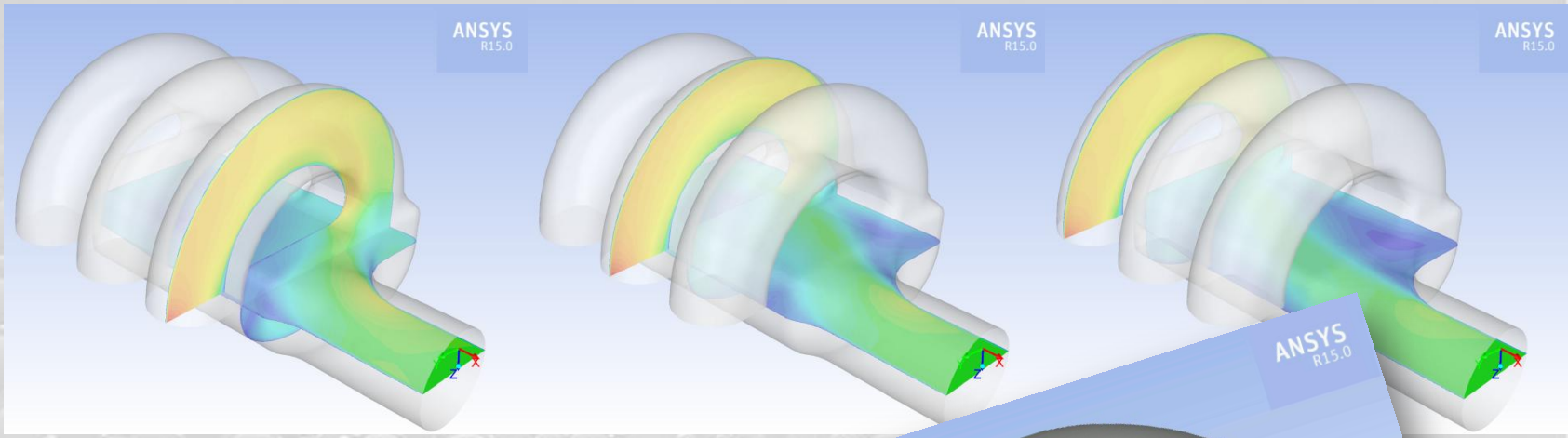
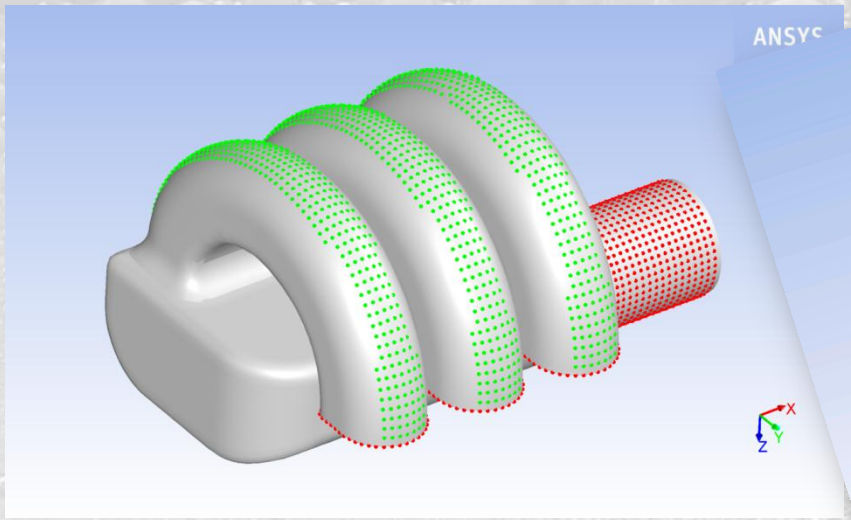
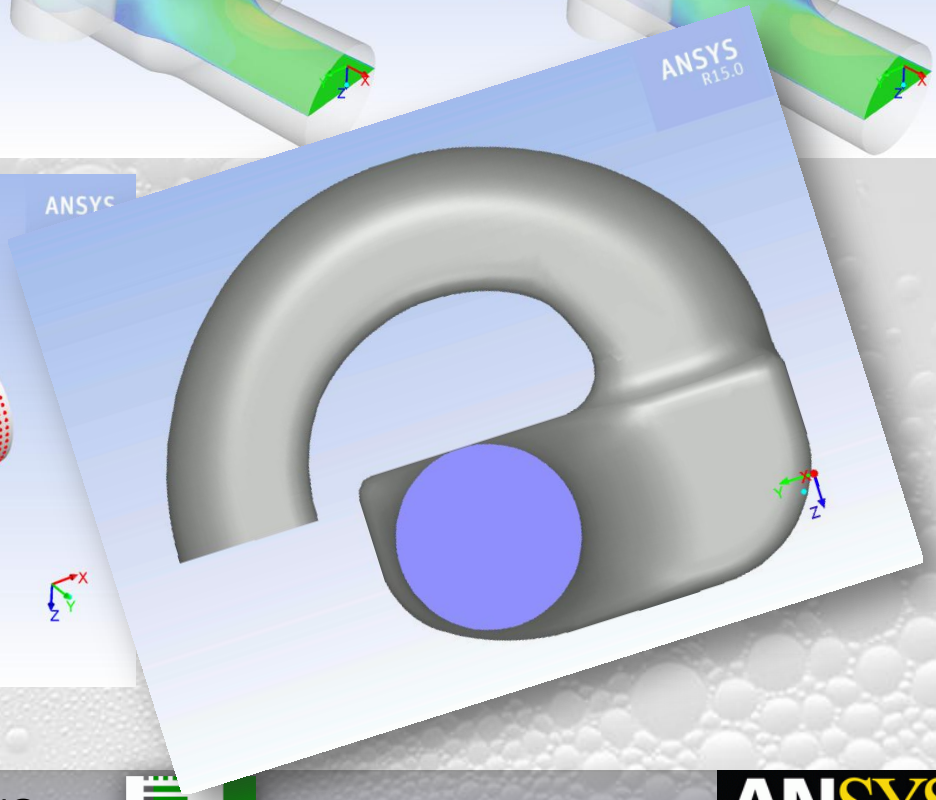
Engine Air box Adjoint shape optimization







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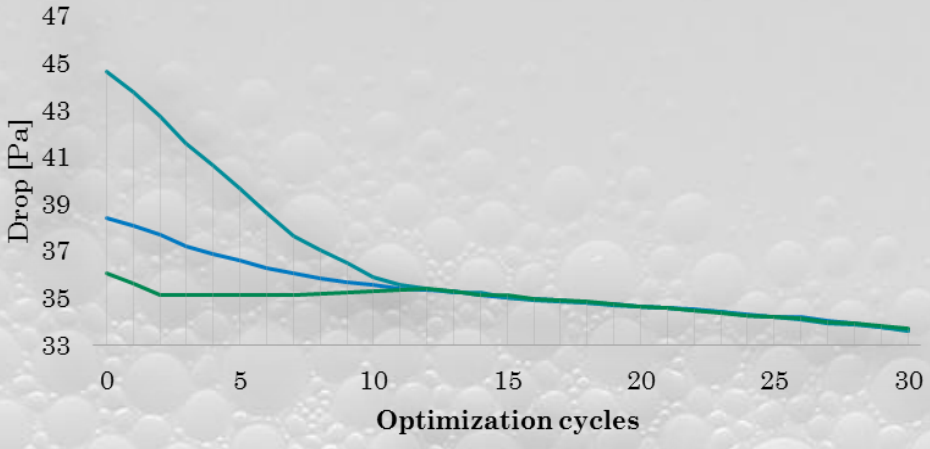
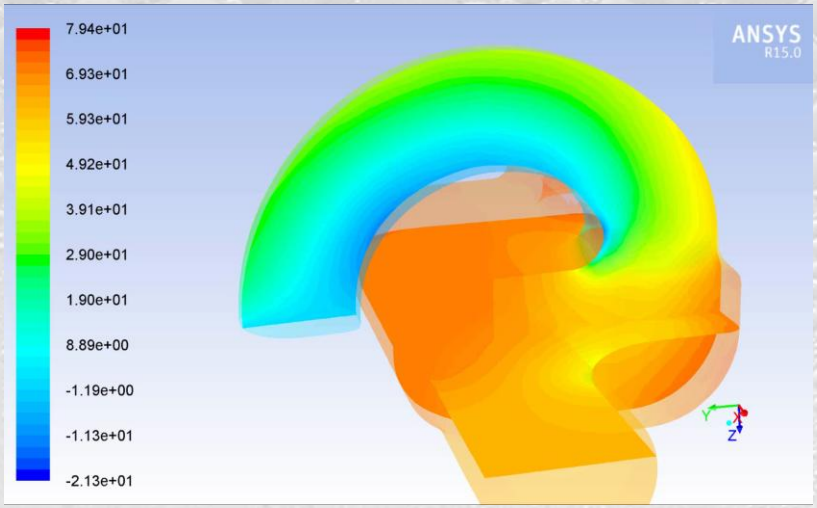
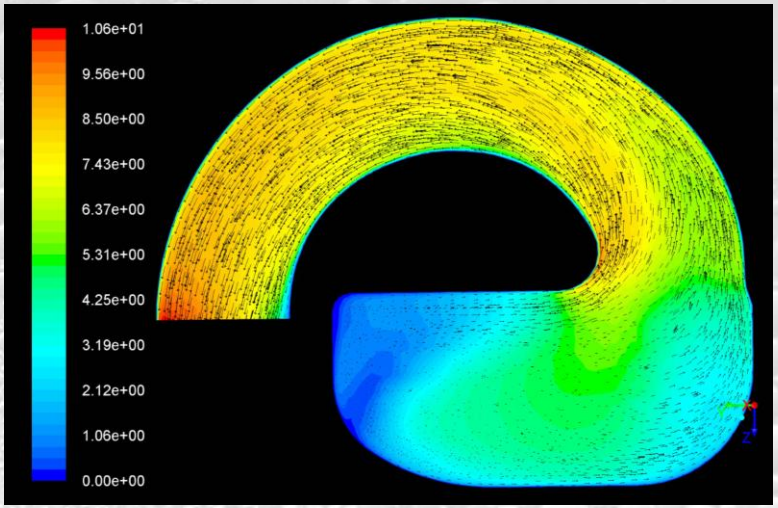
Engine Air box Adjoint shape optimization



	Mean pressure Drop [Pa]	Unbalance
Baseline	39.7	12.45%
Optimized	33.635	0.12%
Reduction	15.3%	99.0%



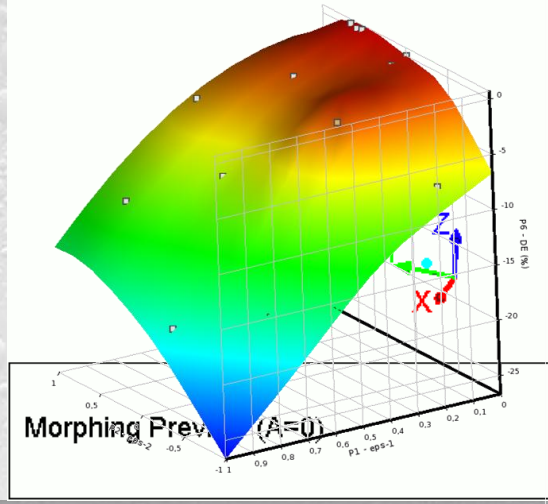


Optimization of sweep angles

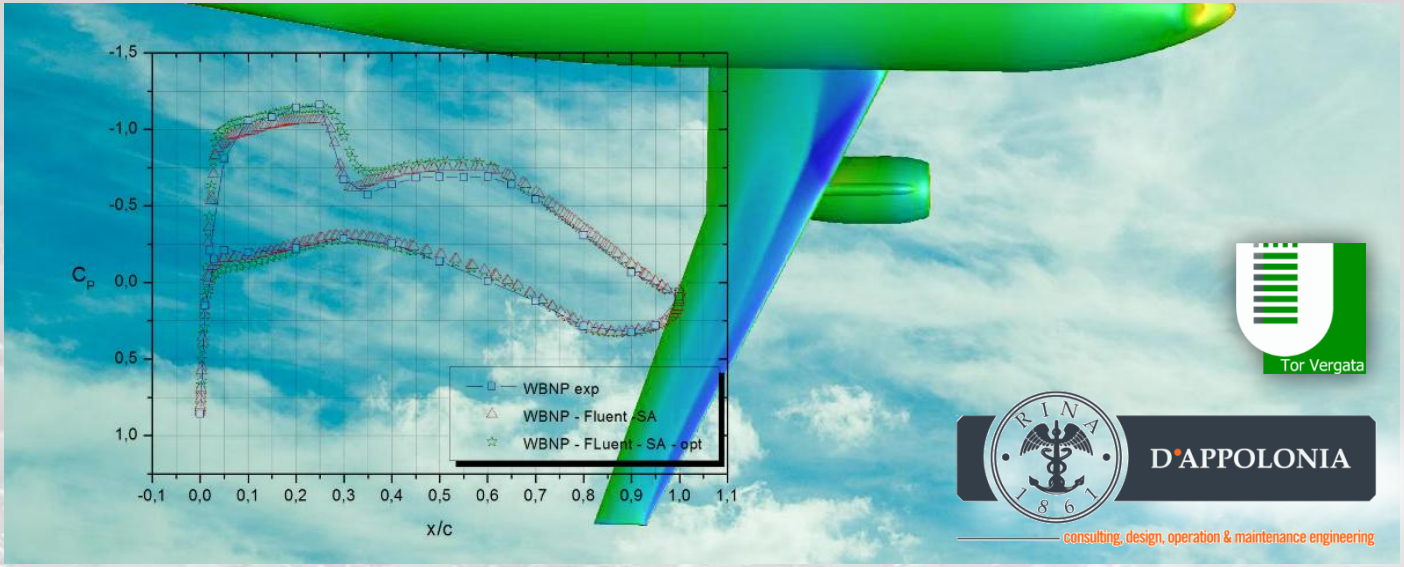
PIAGGIO AERO

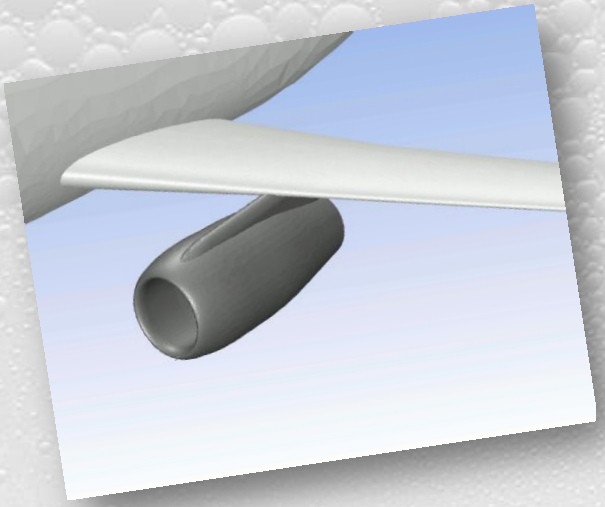
UNIVERSITA' degli STUDI di ROMA TOR VERGATA

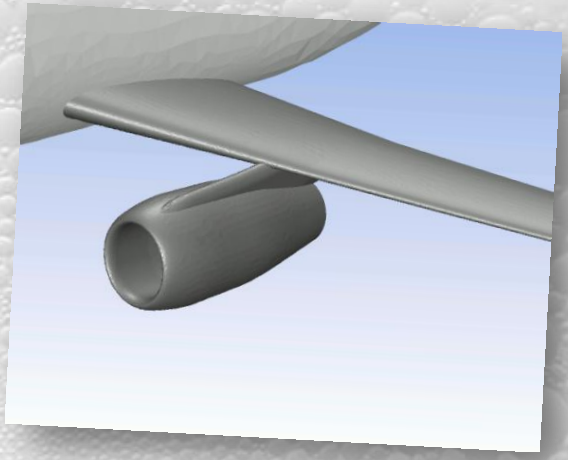
ANSYS 14.0



Optimization of nacelle







MIRA

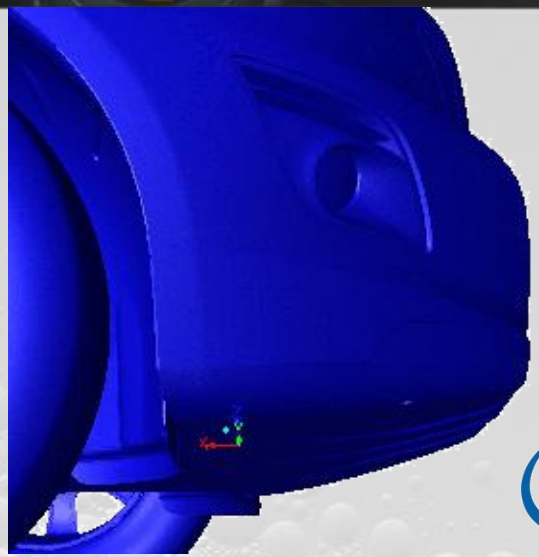
MIRA Reference car (MIRA ltd)

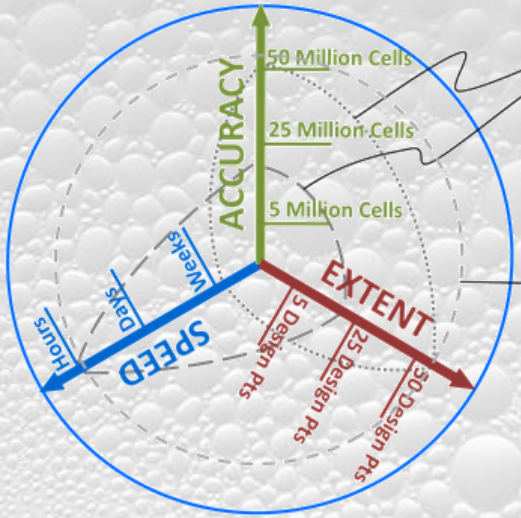
MIRA Reference Car

Shape Optimisation using RBF-Morph

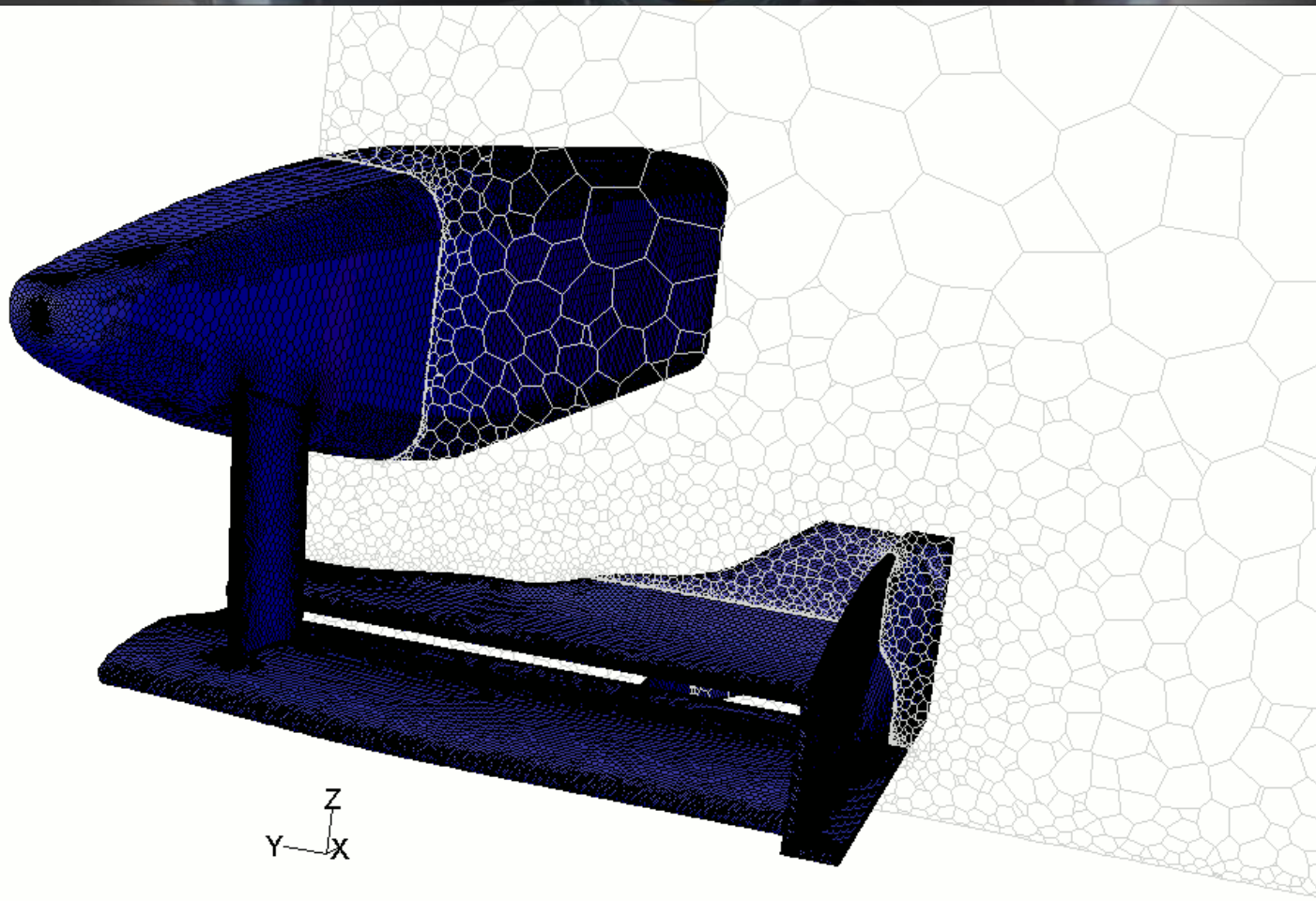
Smarter Thinking.

50:50:50 Project Volvo XC60 (Ansys, Intel, Volvo)



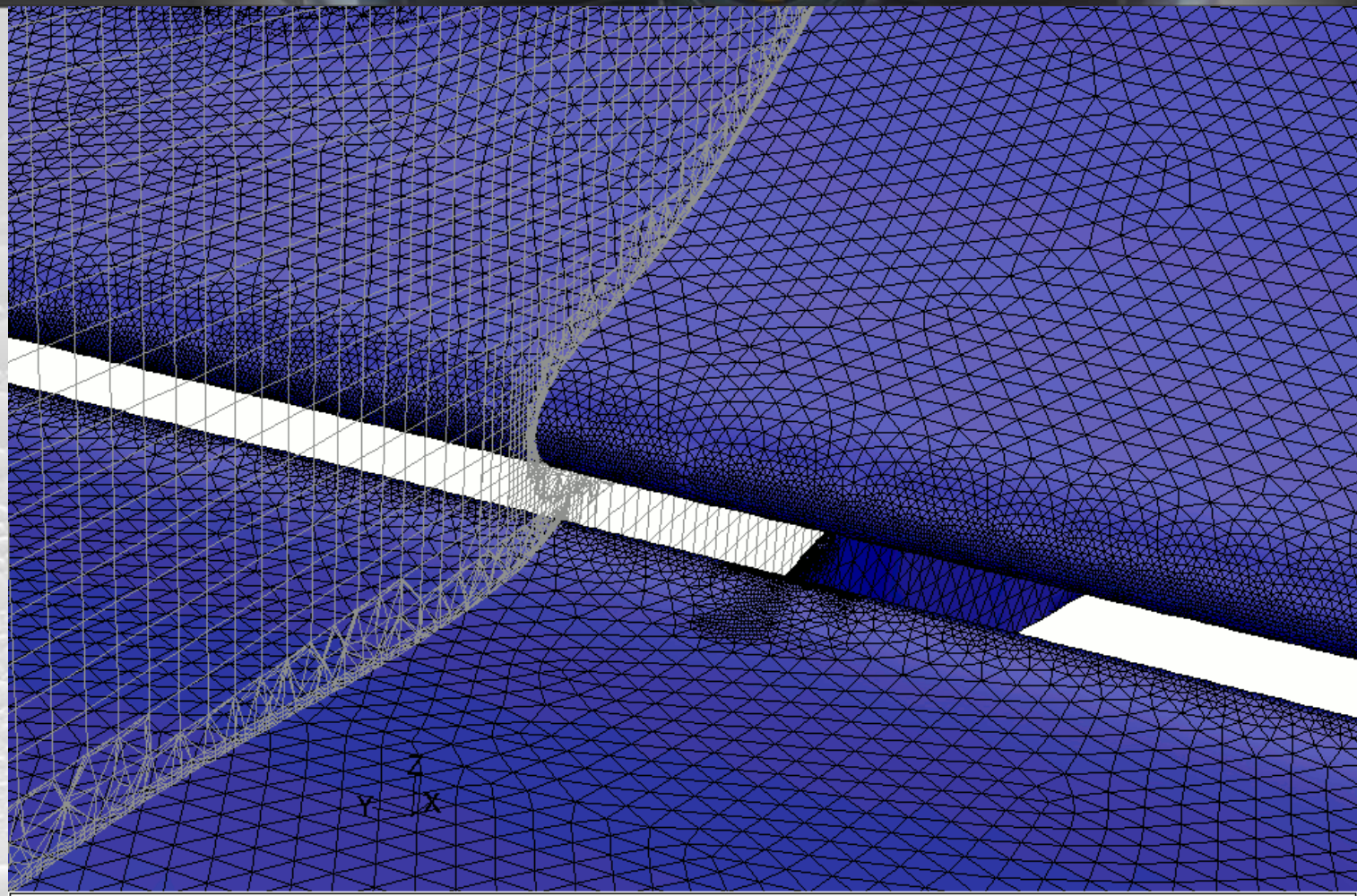


Generic Formula 1 Front End



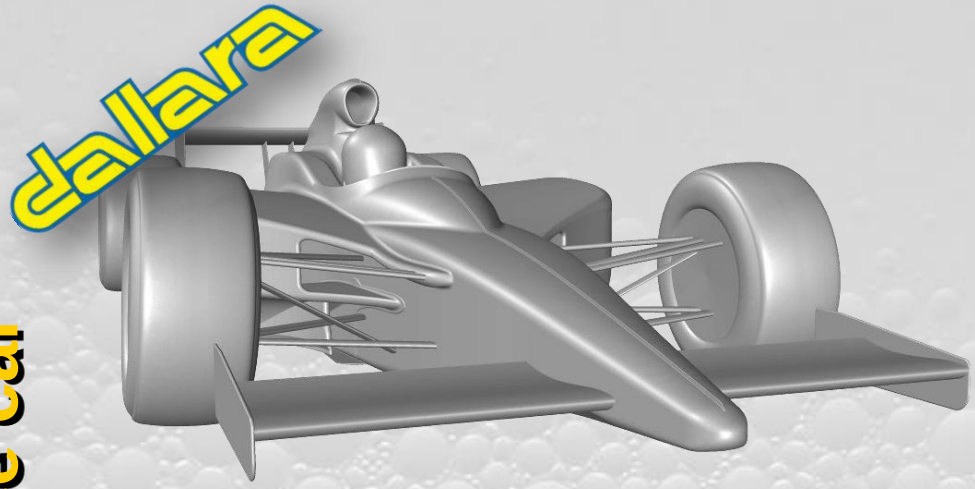
Sol=sol-01-c, A=0
Surface Grid

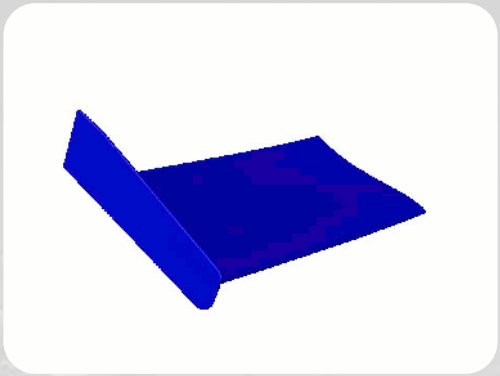
Generic Formula 1 Front End

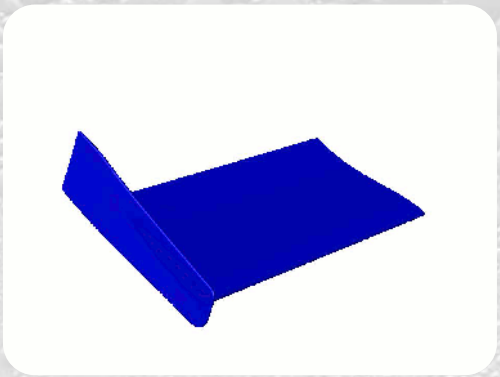


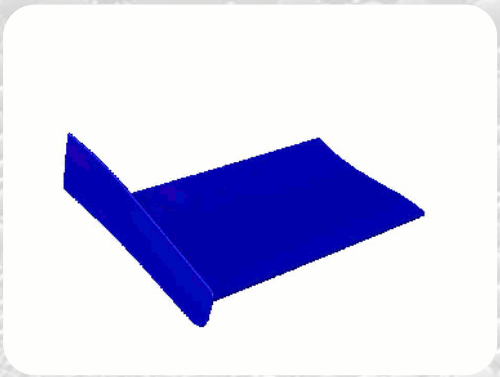
Sol=sol-03-a, A=-5
Surface Grid

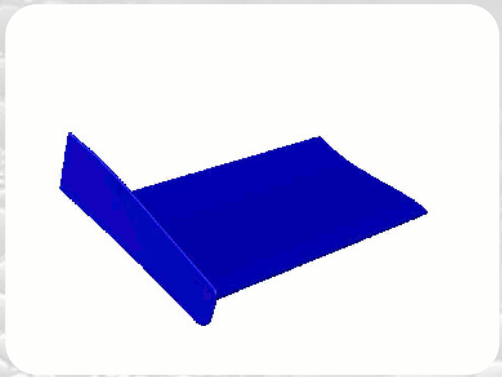
FSI analysis on a Indy race car





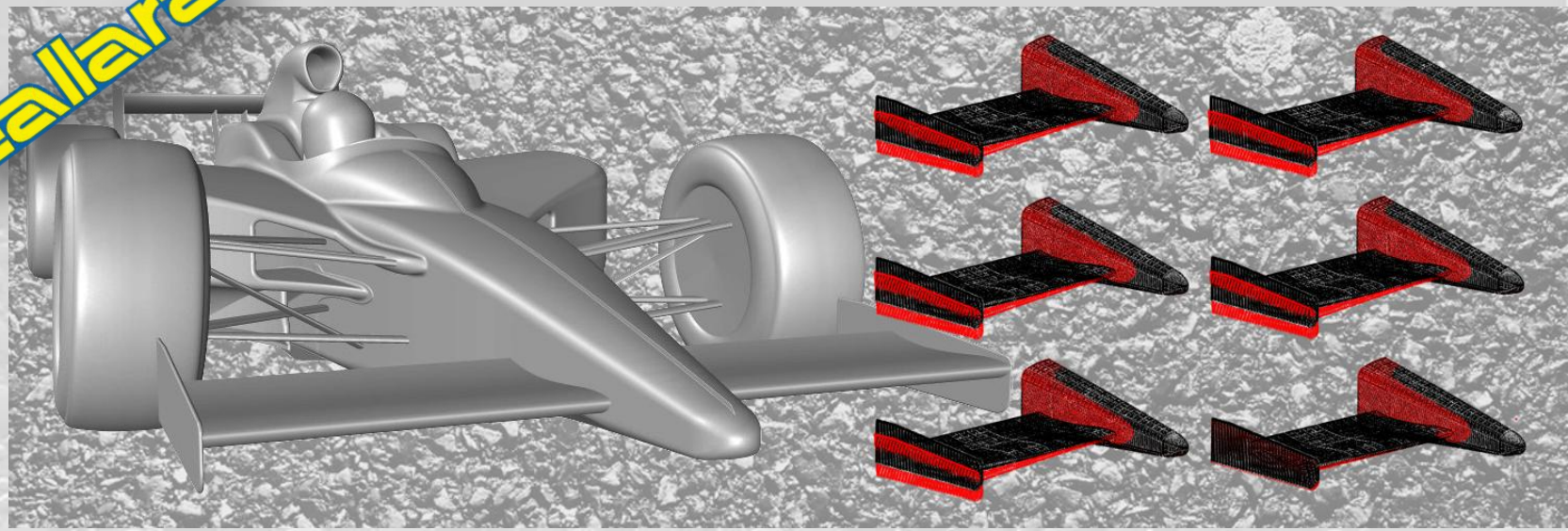






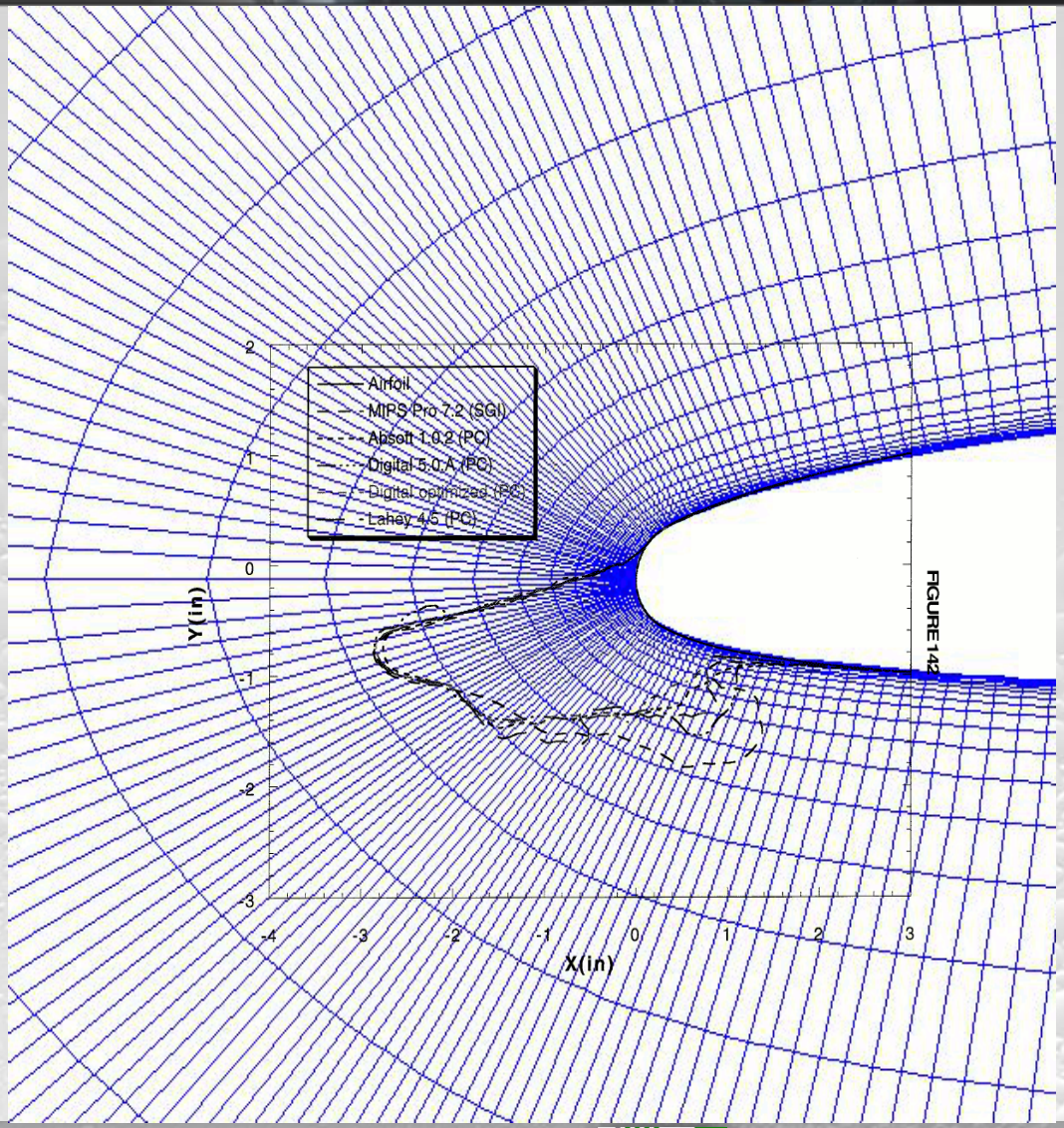
FSI analysis on a Indy race car

dallara



Modes used	Maximum displacement (mm)	Maximum difference (mm)	Maximum error (%)
1	5.941	4.946	8.3
2	5.898	3.817	6.5
3	5.584	1.483	2.7
4	5.56	7.722	1.4
5	5.555	0	0

Ice accretion morphing



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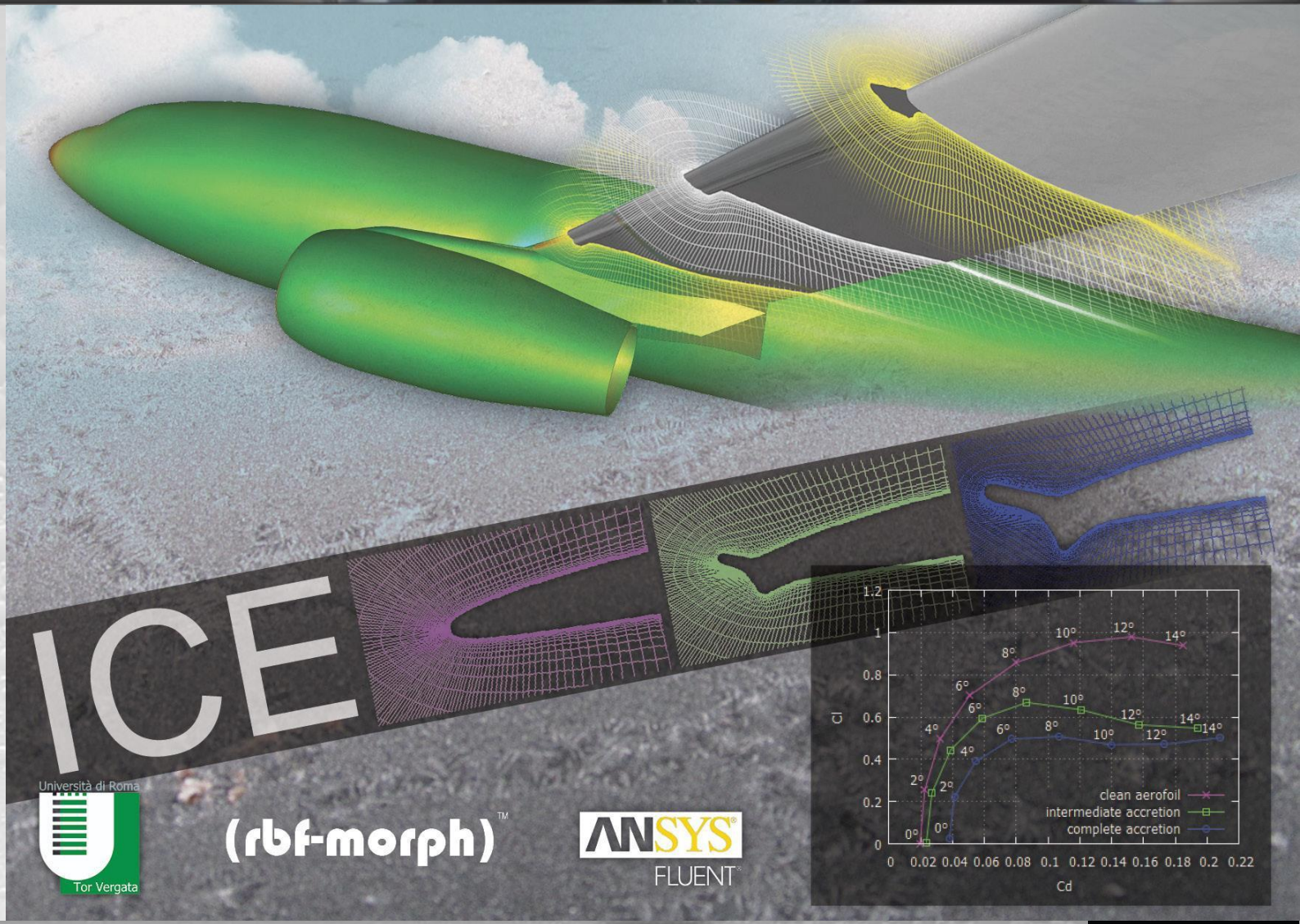
3D accretion morphing



2014 ESSS CONFERENCE & ANSYS USERS MEETING

May 2014 - São Paulo, SP - Brasil

Tor Vergata

ANSYS

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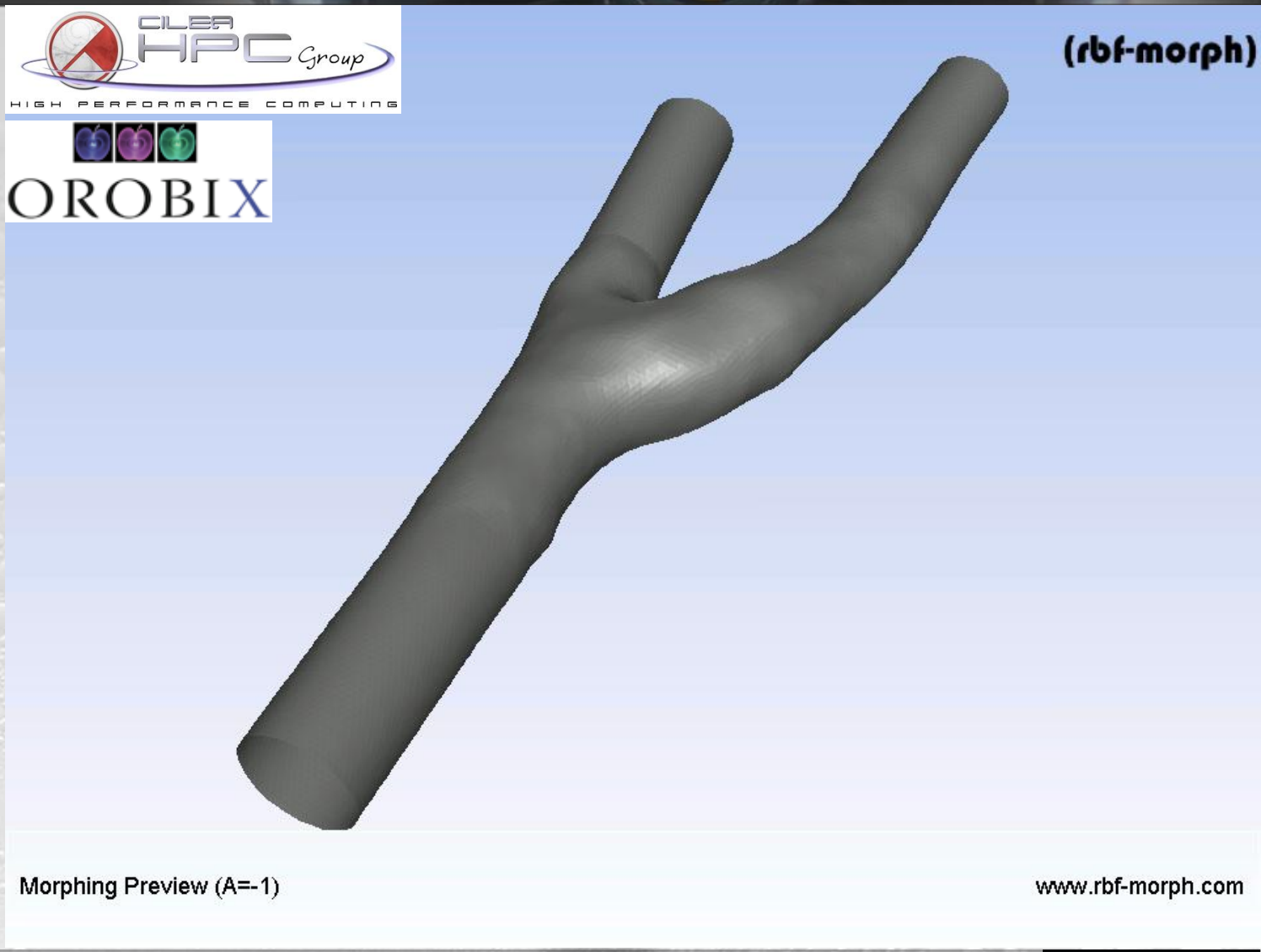

Conclusions

- A **shape parametric** CFD model can be defined using ANSYS Fluent and *RBF Morph* – new stand alone tools allow to widen the range of solvers (CFD, FEA) supported by RBF Morph technology
- **Parametric CFD model** can be easily coupled with preferred optimization tools to steer the solution to an **optimal design** that can be imported in the preferred **CAD** platform (using **STEP**)
- Proposed approach **dramatically** reduces the man time required for set-up widening the CFD calculation capability
- Local mesh control allows to enable multi-physics as well (FSI, icing, adjoint)
- ***M.E. Biancolini****, Mesh morphing and smoothing by means of Radial Basis Functions (RBF): a practical example using Fluent and RBF Morph* in Handbook of Research on Computational Science and Engineering: Theory and Practice (http://www.cse-book.com/)

Muito obrigado pela vossa atenção!

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