RBF Metamorphosis

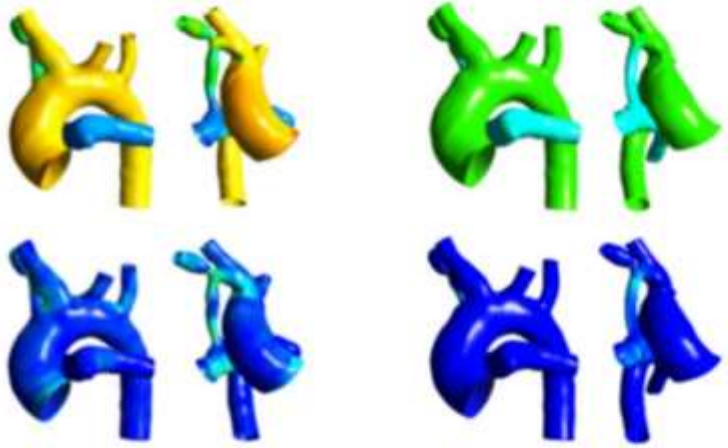
A new way to optimize digital twins and multi-physics simulation

INTERNATIONAL CAE CONFERENCE

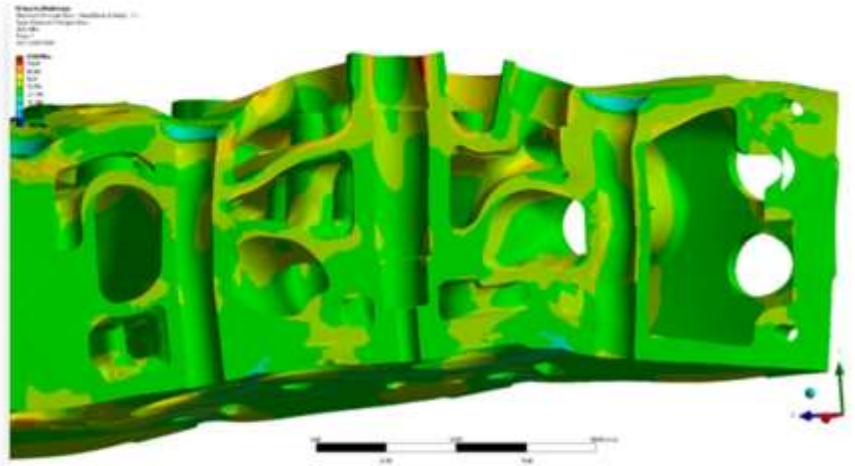
dallara 50 1972 2022

NISSAN

LEONARDO



rbf™



RINA

Cummins

RBF Metamorphosis

A new way to optimize digital twins and multi-physics simulation

16:00	Introduction: Overview of RBF Morph Solutions Marco E. Biancolini (RBF Morph)				
16:10	**Cylinder Head FEA Shape Optimisation with RBF Morph** **Marcel Schubert (Cummins)** FEA and Fatigue Analysis has been carried out as part of the iterative design process of an internal combustion engine cylinder head. The RBF Morph Biological Growth Method has been employed successfully to help provide enhanced design recommendations, reducing the number of design iterations and speeding up the design process.		17:10	**An efficient optimization of air intake based on machine learning and mesh morphing** **Viola Rossano (Leonardo), Andrea Lopez (Univ. Tor Vergata)** Leonardo is creating a digital design and validation environment for the optimisation of a hybrid aircraft. In particular, this activity is focused on the generation of a digital twin from numerical simulations and high fidelity models of a NACA air intake.	
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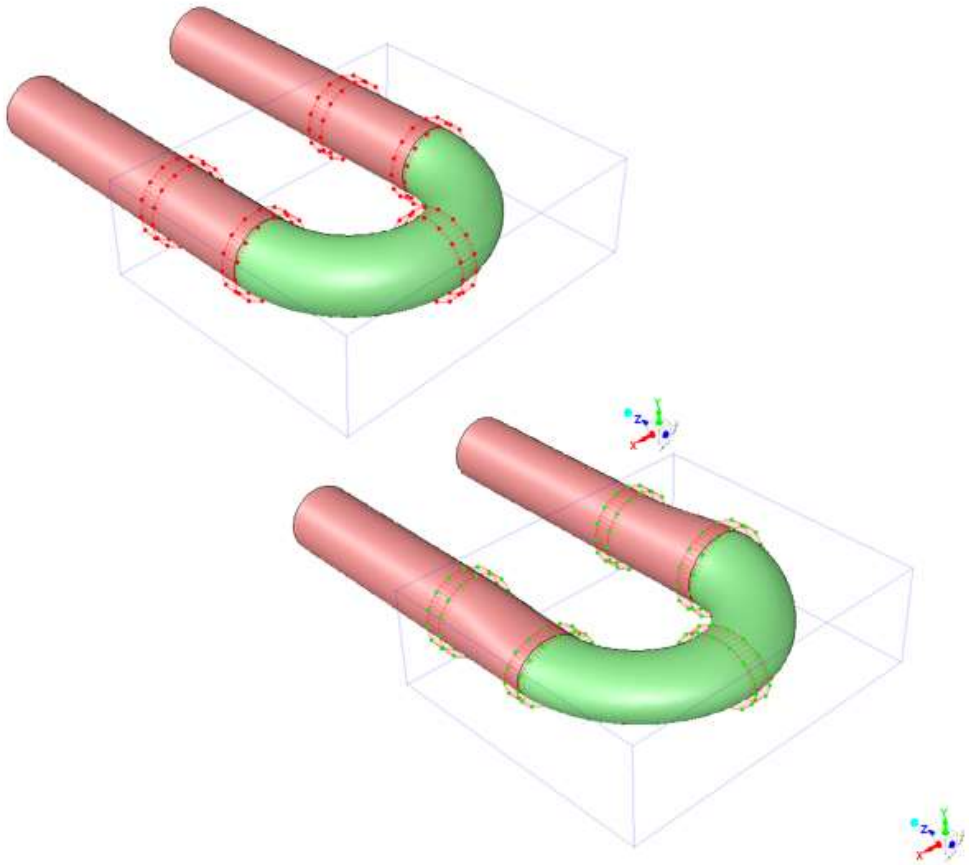
RBF Morph

Optimize your product's performance

Marco Evangelos Biancolini
CTO and company founder

Shape parameterization strategy

- Geometric parameterization by **mesh morphing**
- The principle is to take the control on a set of point and to transfer the deformation to the whole mesh
- A **new shape** of the CAE model **ready to run**
  - for structural analysis in the FEA solver
  - for flow analysis in the CFD solver



Radial Basis Functions mesh Morphing

- We offer **Radial Basis Functions** (RBF) to drive mesh morphing (smoothing) from a list of source points and their displacements.
  - Surface shape changes
  - Volume mesh smoothing.
- RBF are recognized to be one of the **best mathematical tool** for mesh morphing.

$$\begin{cases} s_x(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^x \varphi(\|\boldsymbol{x} - \boldsymbol{x_{s_i}}\|) + \beta_1^x + \beta_2^x x + \beta_3^x y + \beta_4^x z \\ s_y(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^y \varphi(\|\boldsymbol{x} - \boldsymbol{x_{s_i}}\|) + \beta_1^y + \beta_2^y x + \beta_3^y y + \beta_4^y z \\ s_z(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^z \varphi(\|\boldsymbol{x} - \boldsymbol{x_{s_i}}\|) + \beta_1^z + \beta_2^z x + \beta_3^z y + \beta_4^z z \end{cases}$$

Radial Basis Functions mesh Morphing

(rbf-morph)™

Welcome to the World of Fast Morphing!

www.rbf-morph.com

- Main advantages
  - No re-meshing
  - Can handle any kind of mesh
  - Can be integrated in the CAE solver (FEM/CFD/FSI)
  - Highly parallelizable
  - Robust process
  - The same mesh topology is preserved (adjoint/ROM)
  - CAD morphing (iso-brep)

Your next product is your biggest challenge

Companies must deliver more efficient, environmentally friendly but high performing products

Engineering teams are under pressure to do that while reducing costs and lead time

Optimization through digital tools is the only feasible way, but it requires a lot of expertise and each tool is different

We help you to simplify and solve it

We provide companies and research institutions with a set of **proven** and **reliable** tools to **quickly optimize each product's shape**, increasing mechanical and aerodynamic performances.

Our goal is to **make it easy** for every designer and engineer through:

- Highly automated tools
- Guided workflows
- Easy to use interface
- Easy to interface with main CAE software: CFD, FEM, FSI

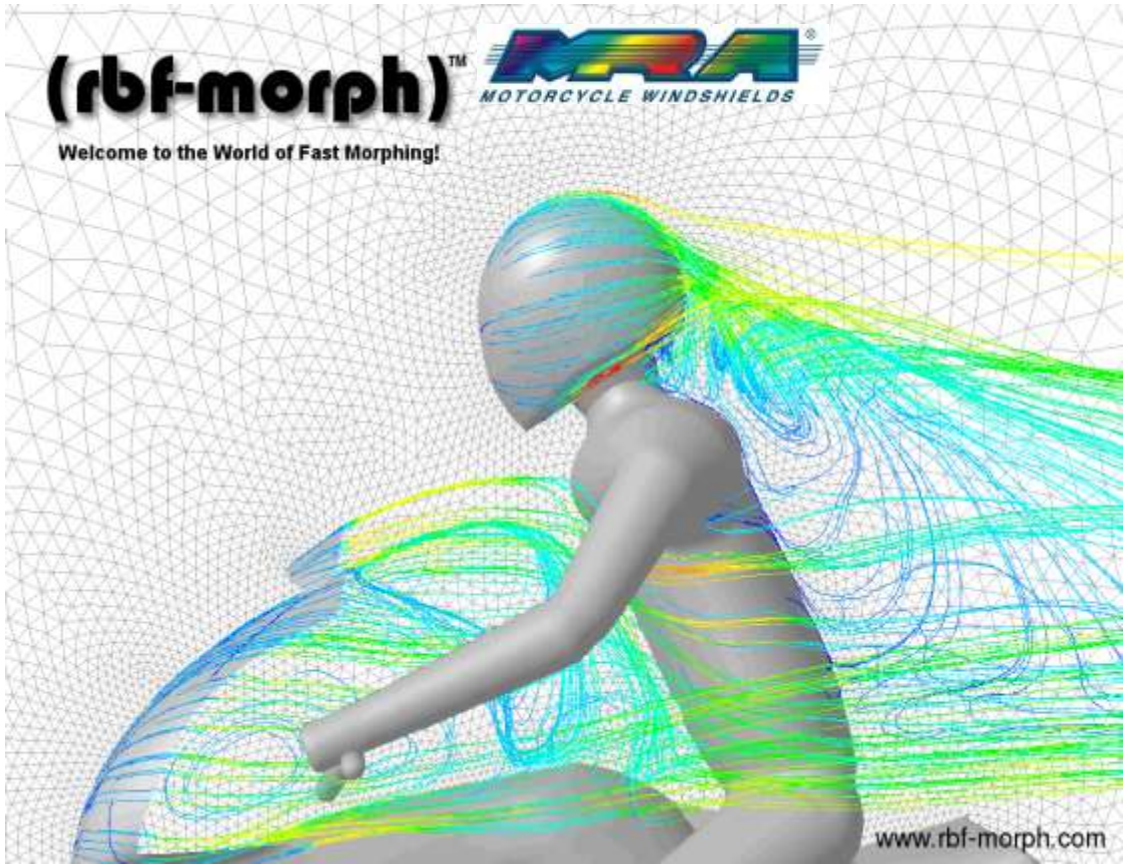
We make CAE models parametric

CAE models supported includes flow analysis (CFD) and structural analysis (FEM)

RBF Morph makes the CAE model parametric with respect to the shape.

Works for any size of the mesh.

Shape parameters can be steered with the optimizer of choice.



Through powerful RBF methods

No re-meshing: very fast, even for complex shapes and any kind of mesh

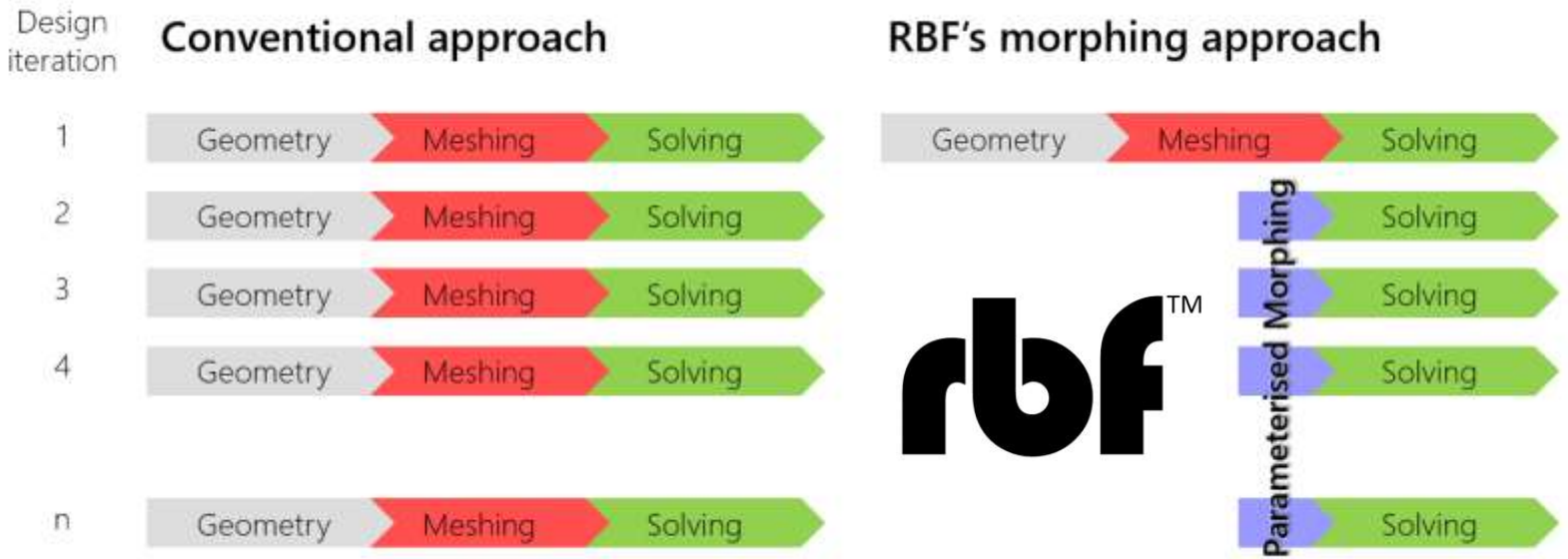
Very effective: up to 15% performance improvement

Can be integrated in CAE solvers (FEM/CFD/FSI)

Highly parallelizable

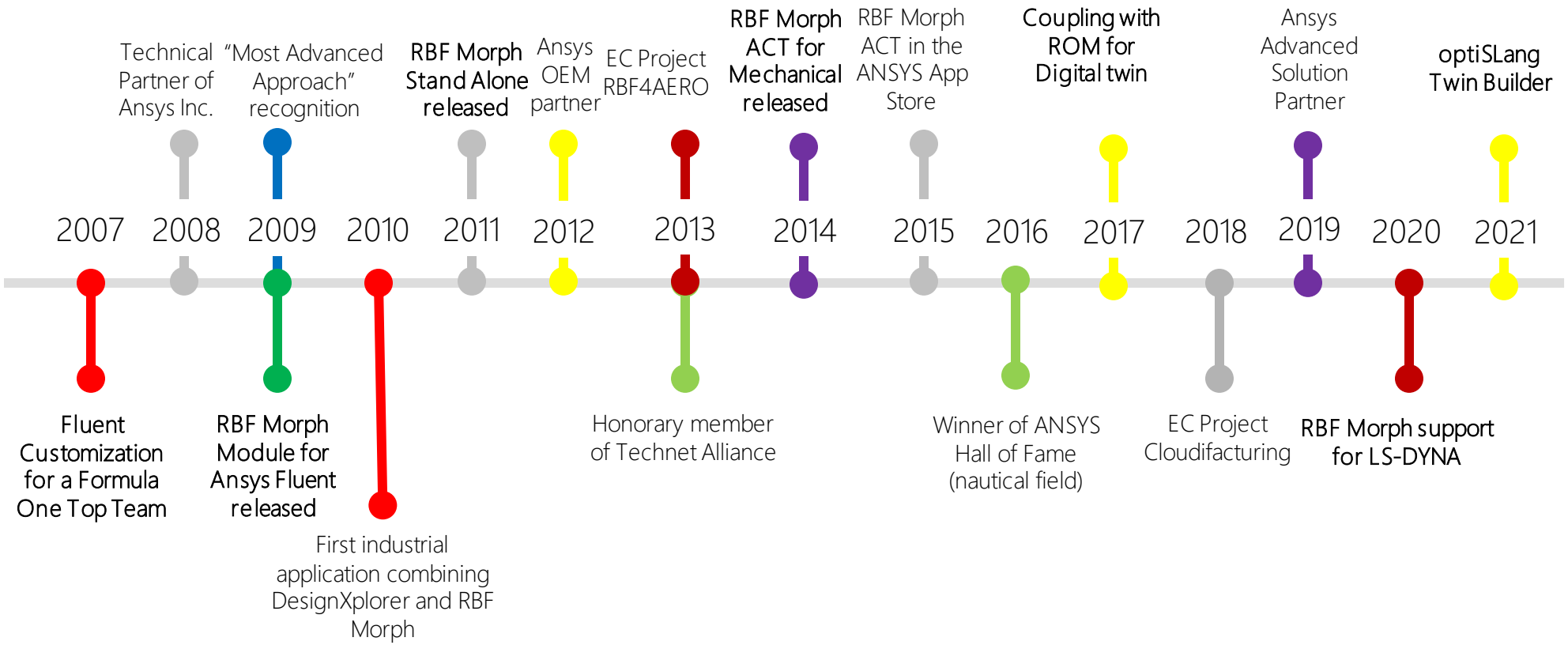
Robust process, proven in safety-critical industries

Saving time and money



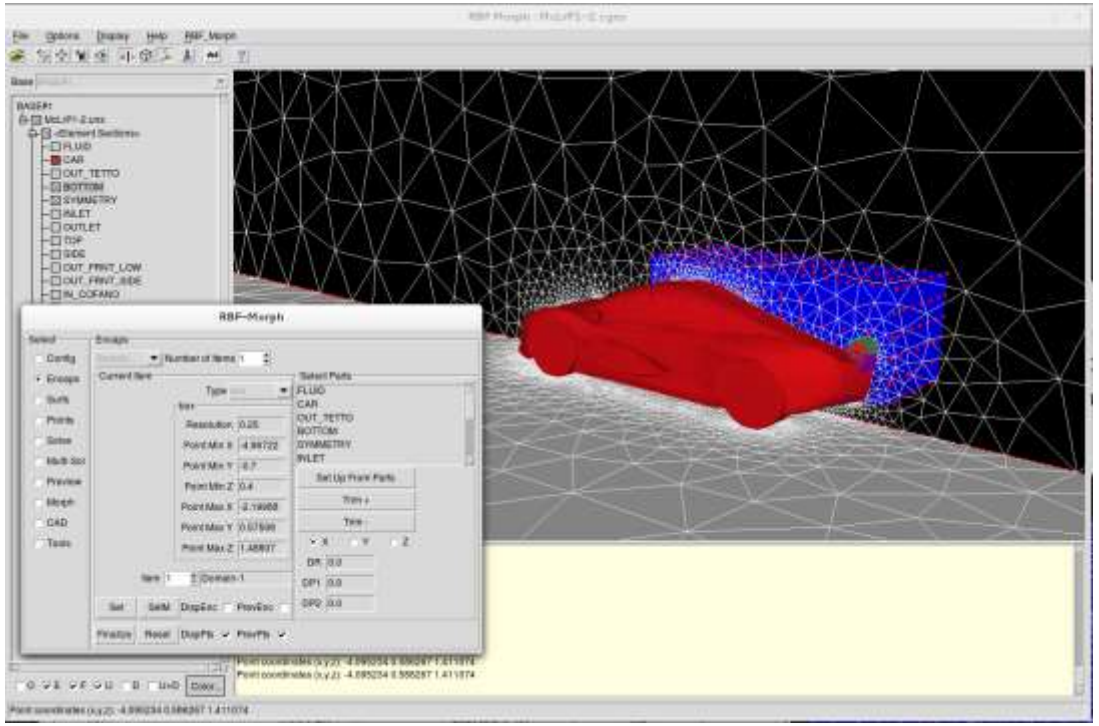
- It's **easy and fast**: shape parameters are defined in the CAE GUI. No need to iterate the CAD.
- The turnaround time of the optimization is usually **reduced by a factor five** (weeks becomes days)

A solution based on 10+ years of experience



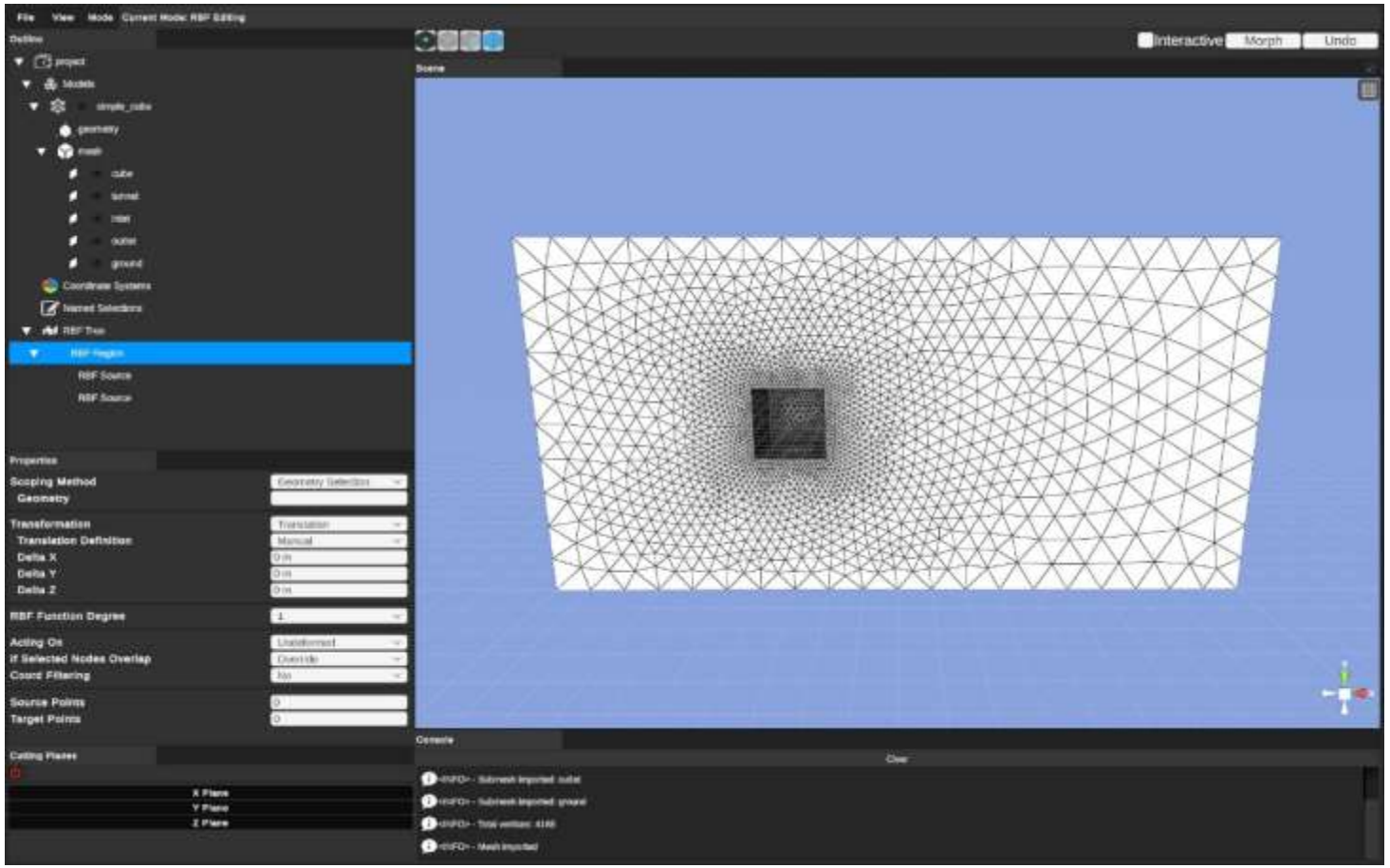
100+
Global Customers

Stand Alone software



- Released in 2011
- Read in **STL and CGNS file formats**.
- Solver independent process that supports **many mesh formats**
- **Scriptable** via tcl

New Stand Alone software (RBF2CAD)

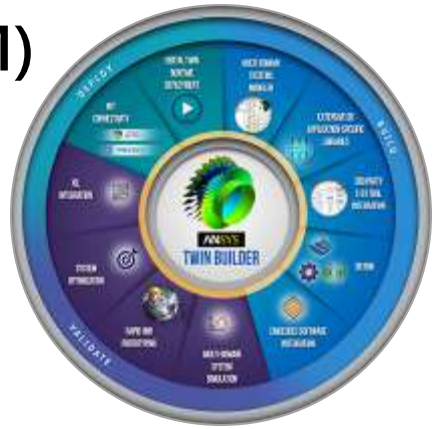


- To be released in 2022
- Read in **STL, CGNS, STEP**
- **Unity - OpenCascade**
- Solver independent process that supports **many mesh formats**
- **Scriptable** via python

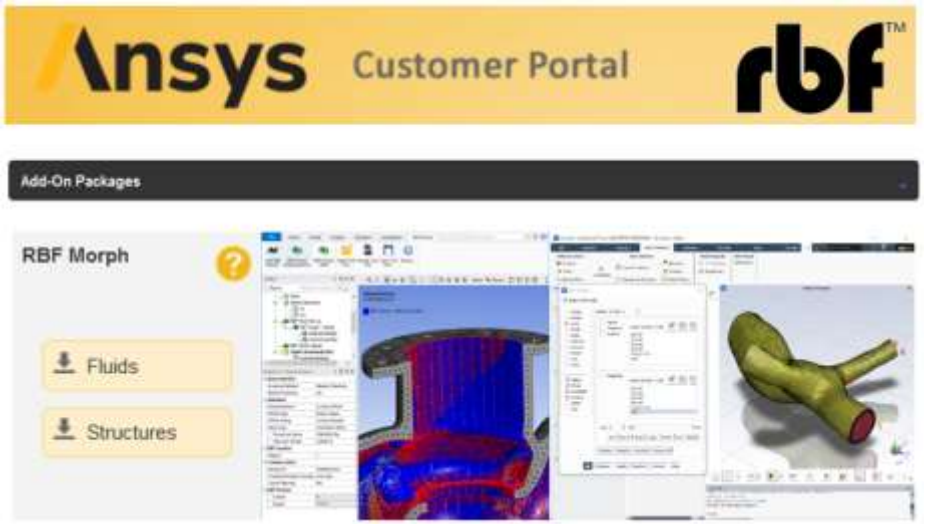
Ansys integrated solutions

RBF Morph Structures (FEM)

- Released in **2014**
- Fully embedded in ANSYS **Mechanical** (parametric)
- Benefits of **underlying geometry** (or aux geo with dead meshes)
- …**WB** Meshing



Ansys OPTISLANG

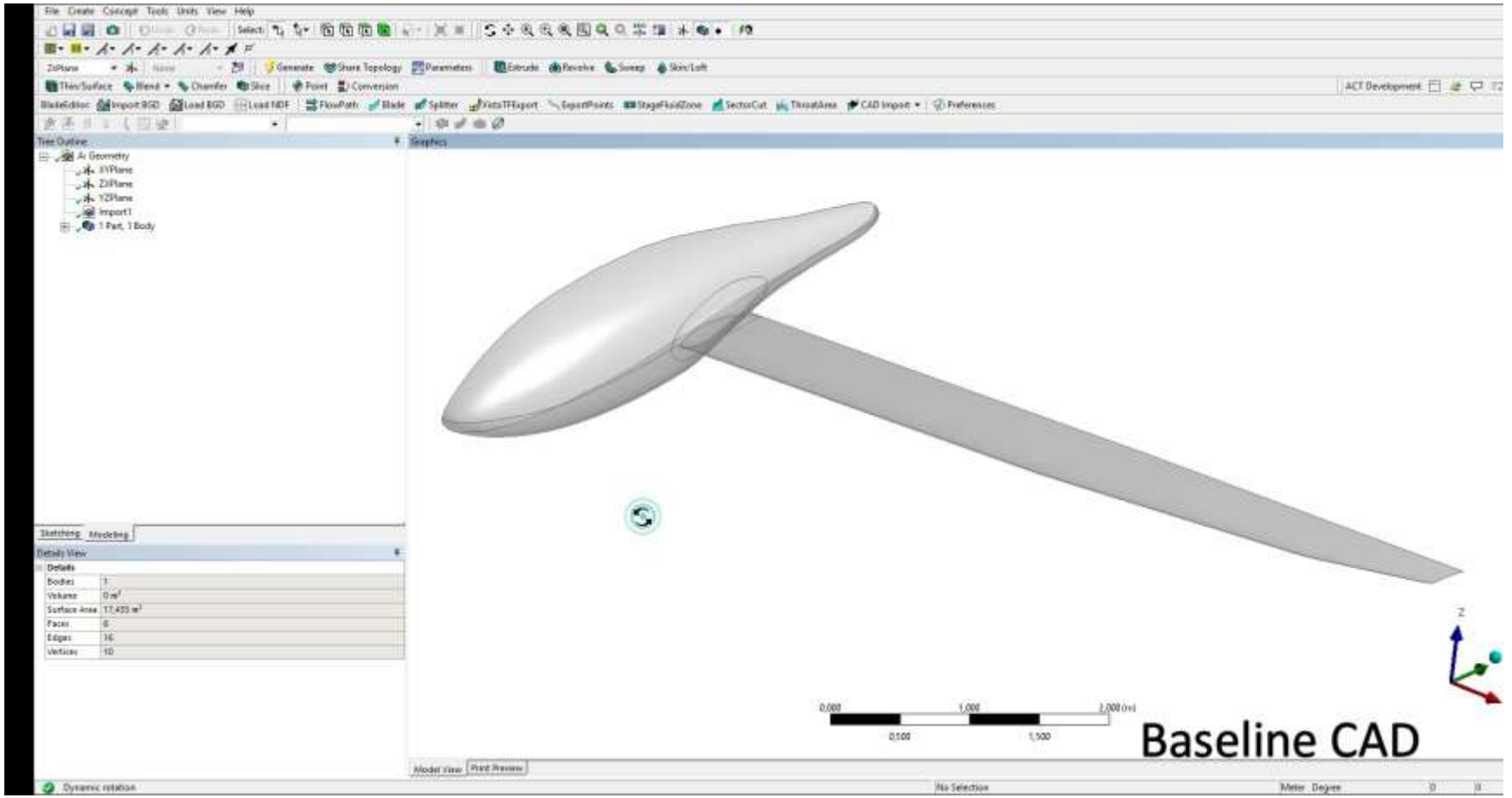


RBF Morph Fluids (CFD)

- Released in **2009**
- Fully integrated within Fluent (GUI, TUI & solving stage), Workbench and **Adjoint Solver**
- Multi physics features (**FSI**)

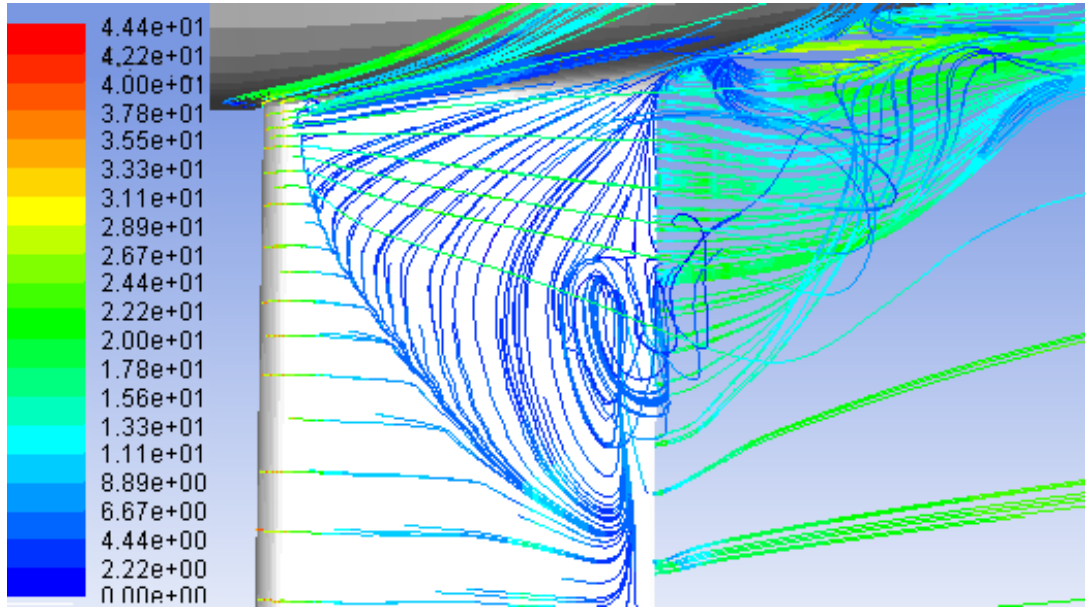
RBF Morph Fluent Module

https://youtu.be/EWsigyqByRg

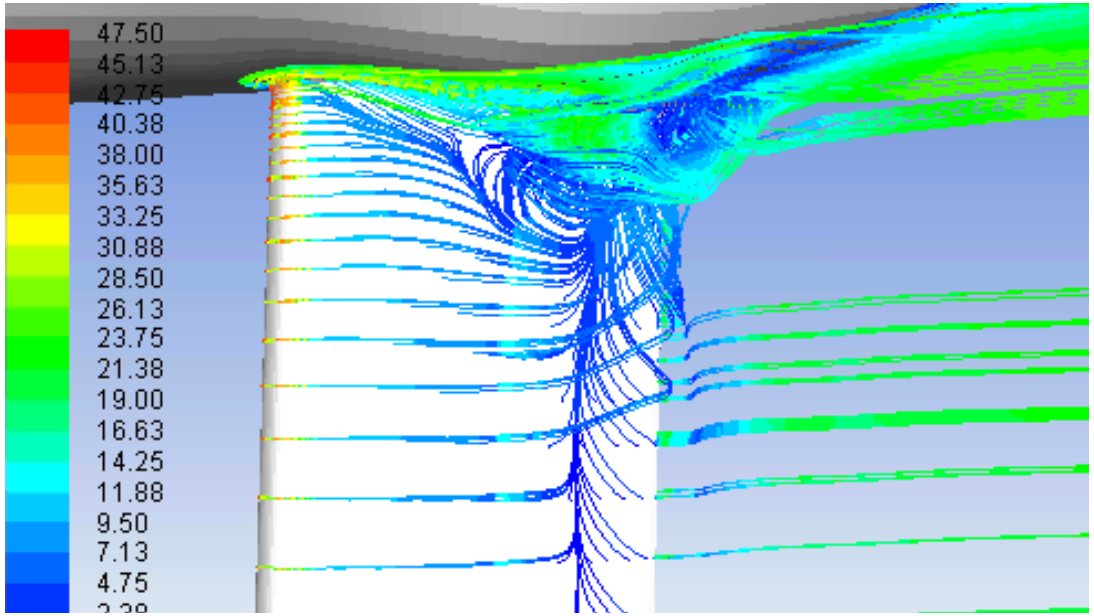


Glider optimization

Original design E=14.9

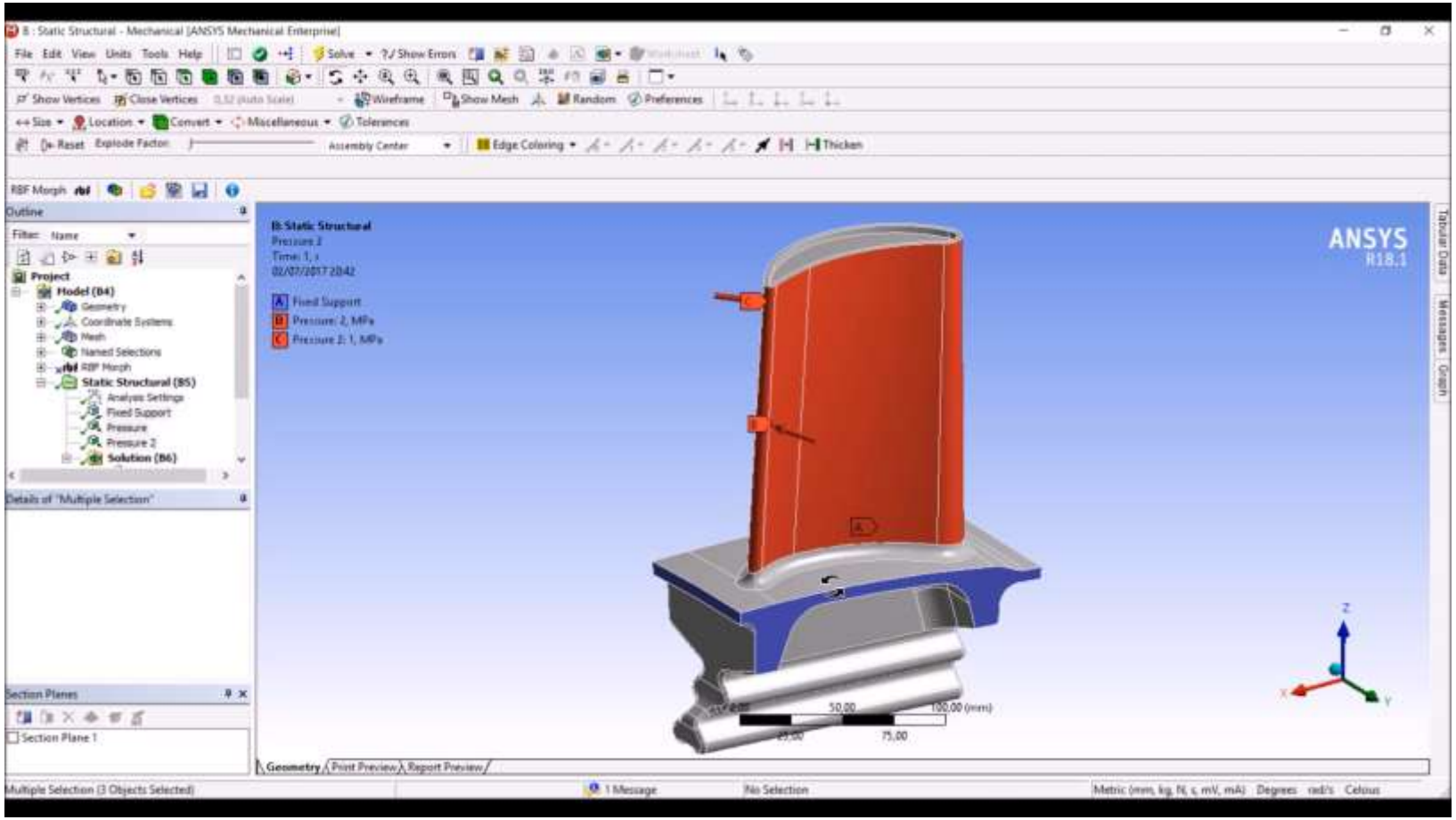


Optimal design E=20.1 (+35%)

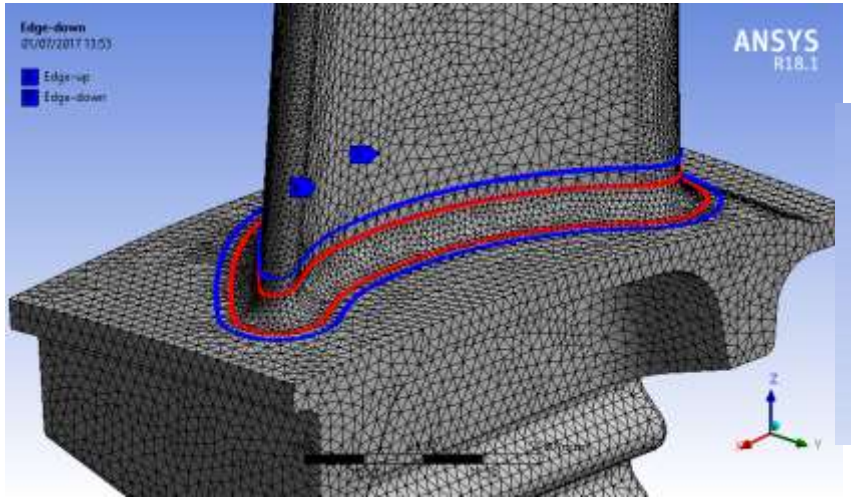


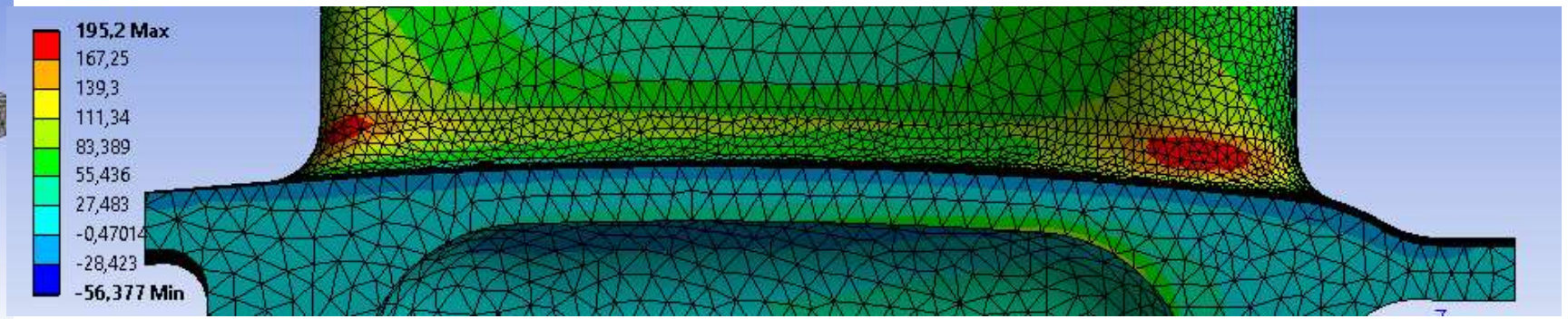
RBF Morph ACT Extension

https://youtu.be/TUOJGAG7Wtk

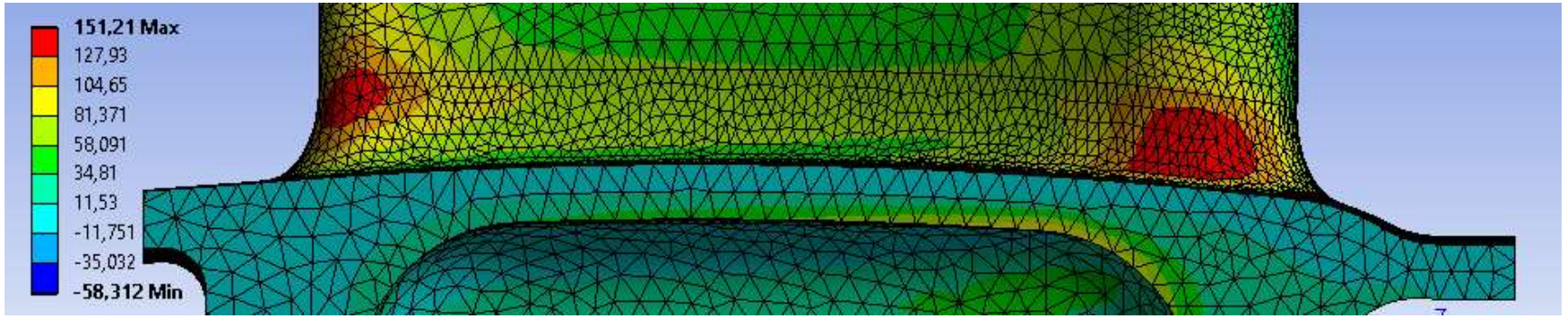


Blade fillet stress reduction





Two parameters allow to get a 22.5% stress **reduction**



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youtube.com/user/RbfMorph

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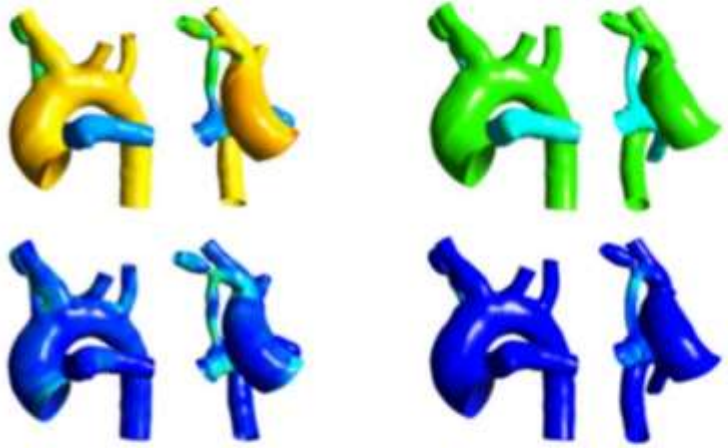

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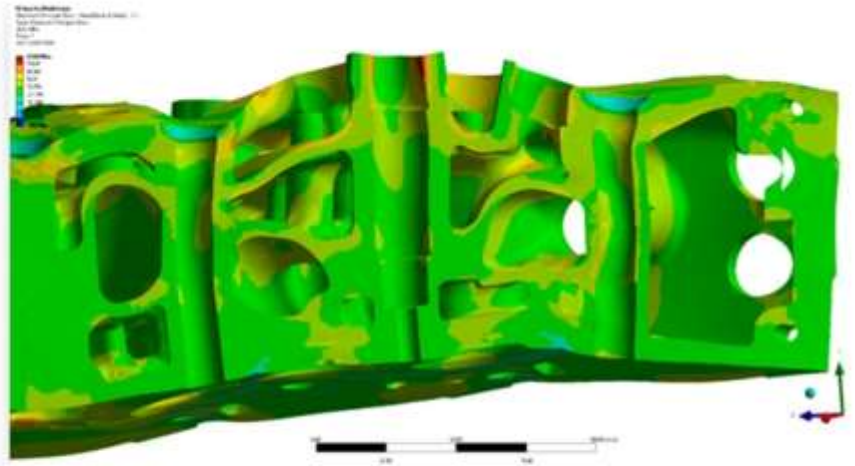
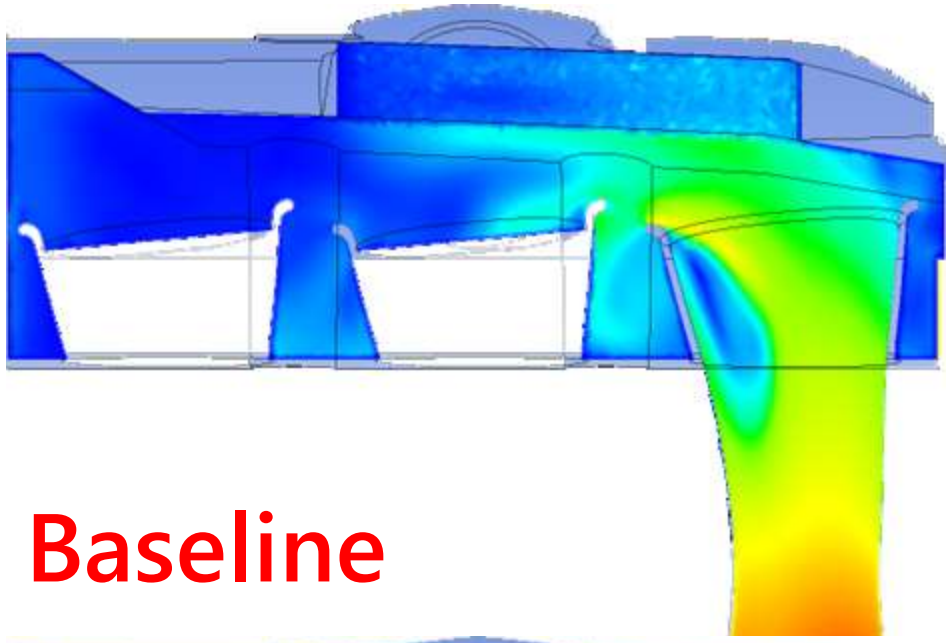


RINA

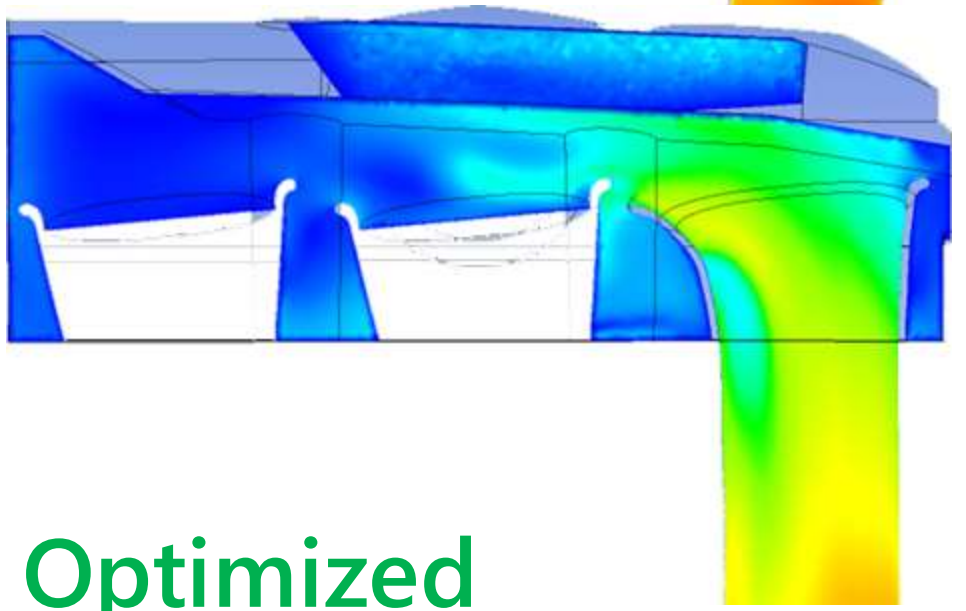
Cummins

Applications

Advanced workflows powered by RBF Morph

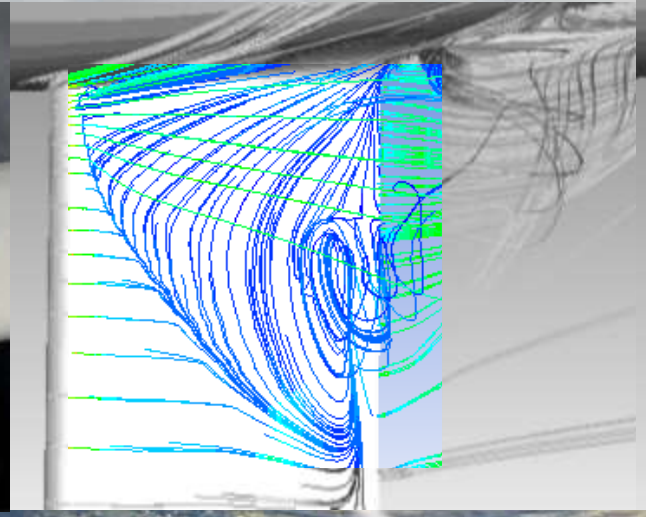


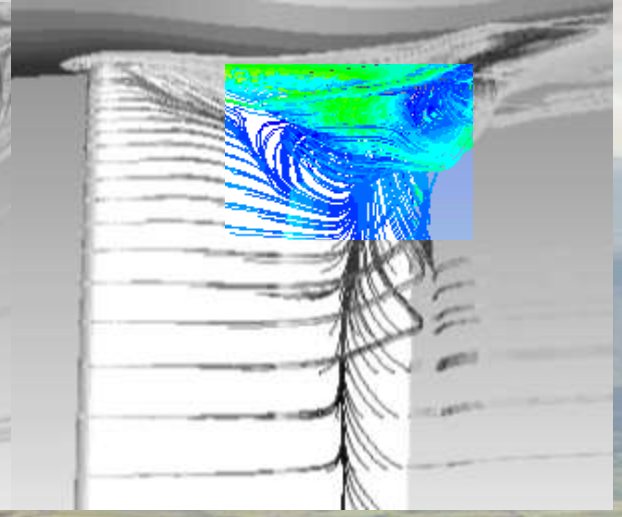
Baseline



Optimized
-5.9% pressure drop

Lamborghini Aventador engine air box

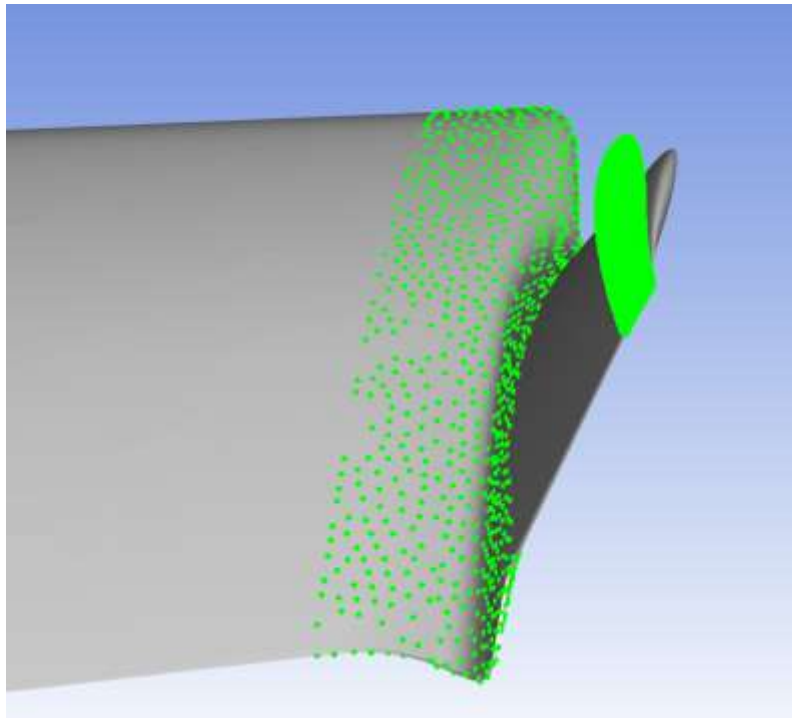




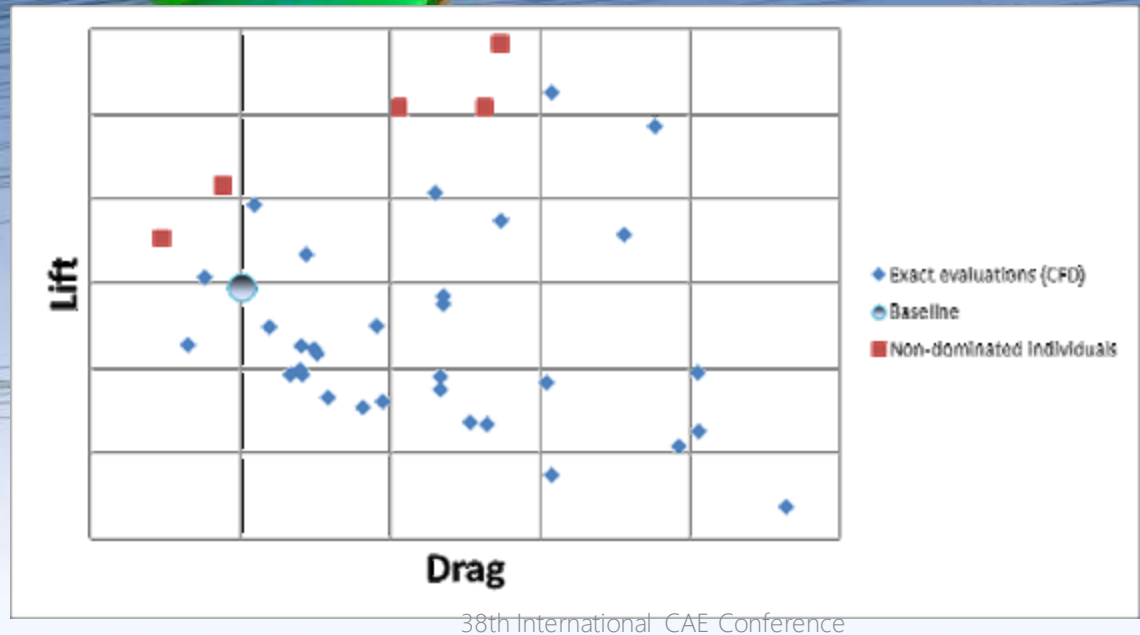
Glide further!

35% more wing efficiency

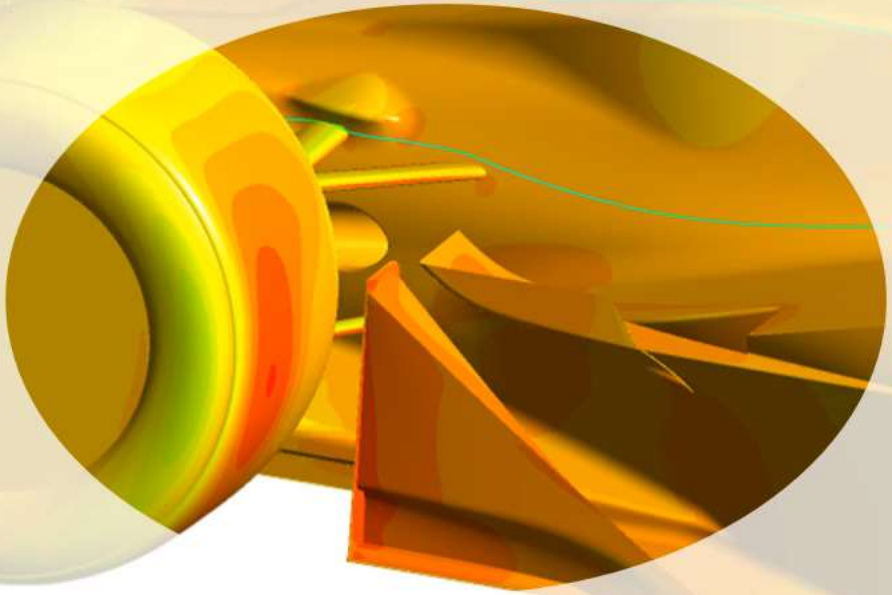
FSI winglet optimization



Range extended by 12%



Drag reduction of a dallara Indy car (-0.98%)

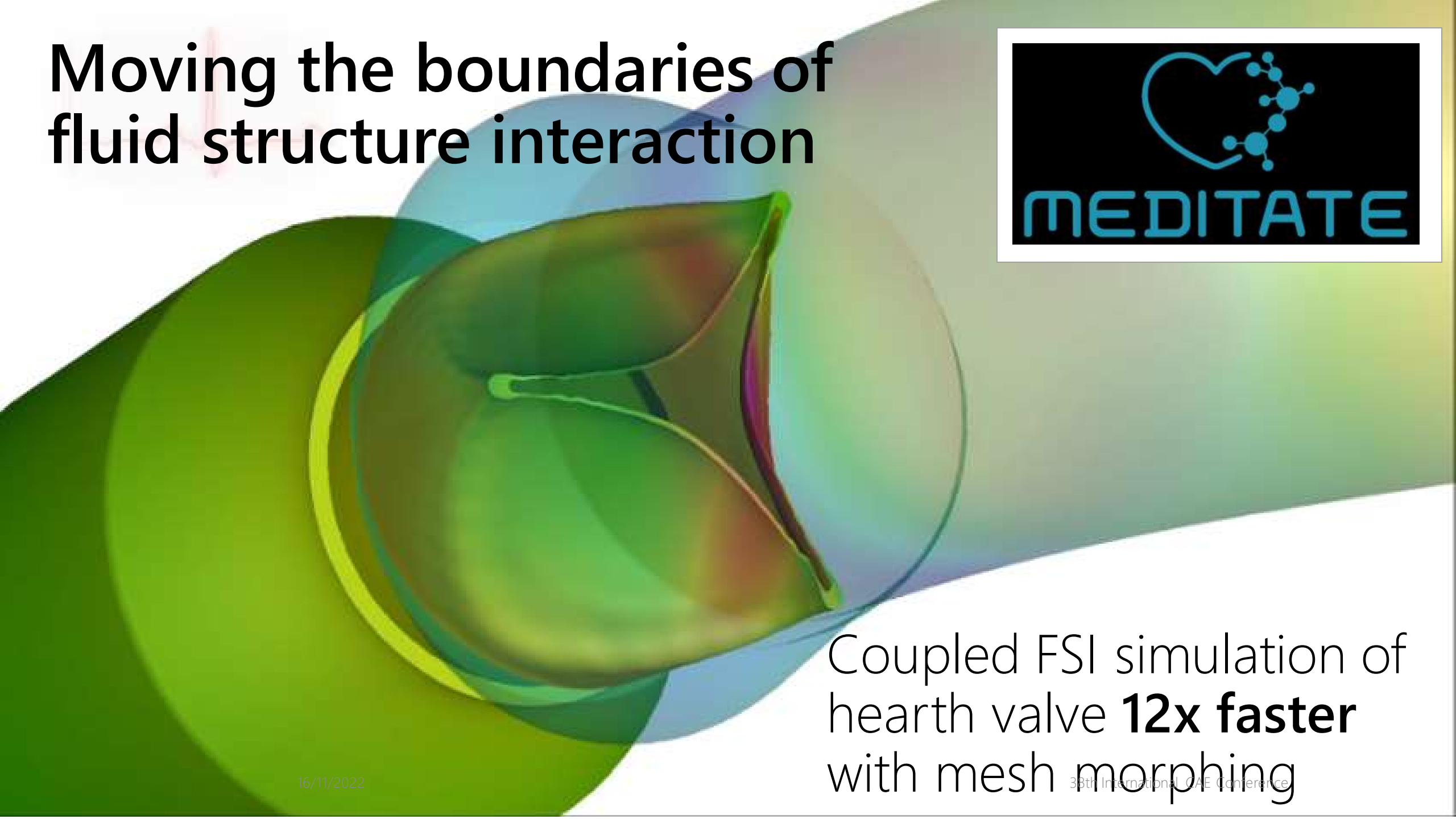


Original shape

Alpha Electro Propeller

- Mesh morphing for shape **parametrization** of numerical grids (CFD/FEM)
- FSI based on mapping and modal superposition
- Performance of the **propeller** are optimised for the specific needs of **electric propulsion (+4% efficiency)**

Moving the boundaries of fluid structure interaction



MEDITATE

Coupled FSI simulation of hearth valve **12x faster** with mesh morphing

DRAGONFLY

Simulation of 2-D tandem wings

(Vorticity)

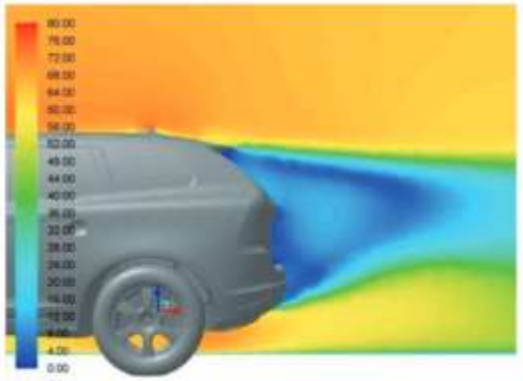
TOR VERGATA
UNIVERSITY OF ROME

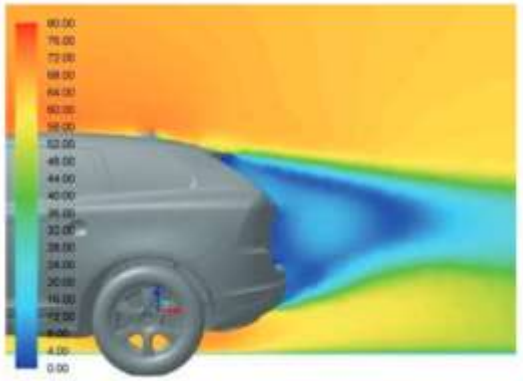
Bio-inspired locomotion

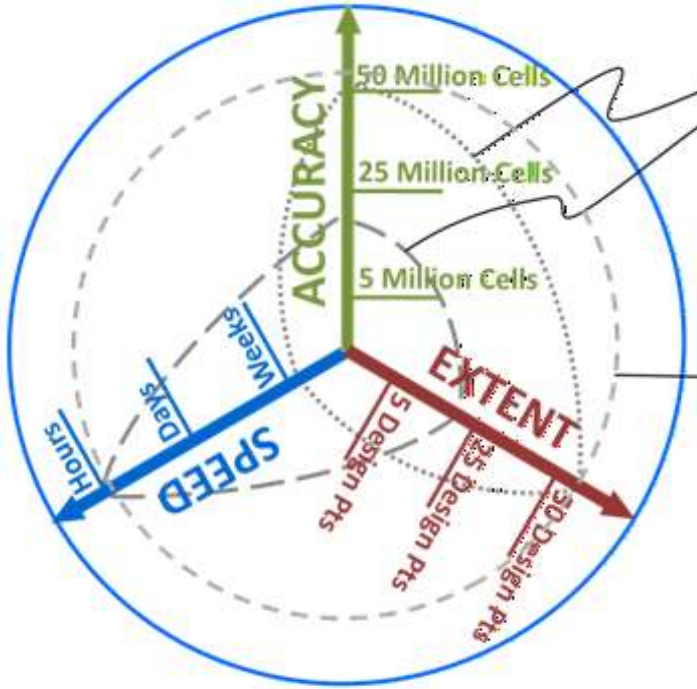
2.4x propulsive efficiency with FSI

50:50:50 Project Volvo XC60

5% drag reduction







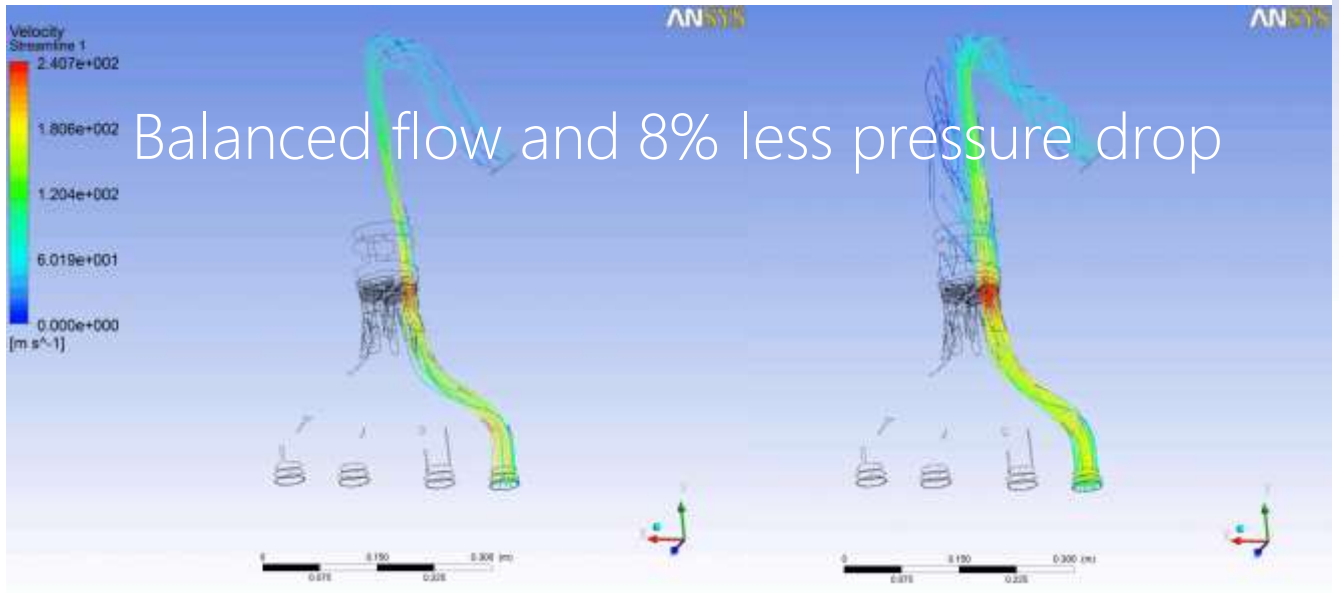
Prior aerodynamics optimization processes have either achieved speed at the expense of accuracy and extent or vice versa

The goal of the current work is to achieve speed without compromising accuracy or extent

Exhaust manifold

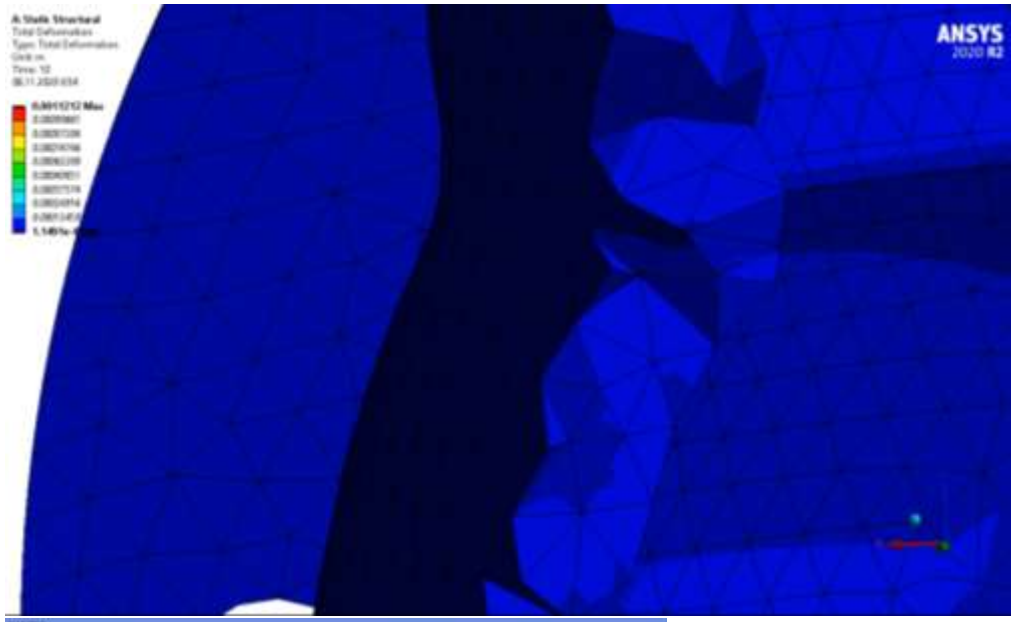
Table of Design Points

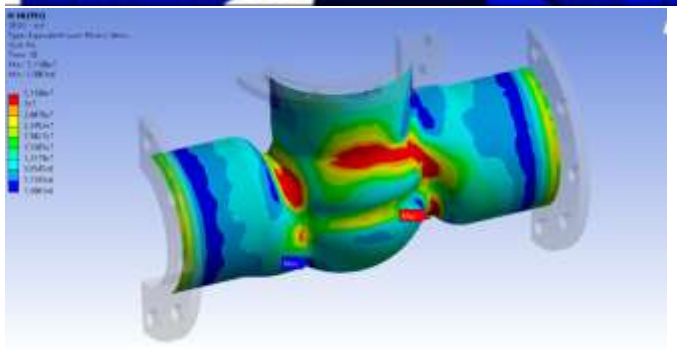
	A	B	C	D	E	F	G	H	I
1	Name	P5 - Pipe1Curve1	P6 - Pipe2	P7 - Pipe4Curve1	P8 - Pipe3	P1 - PressureDrop1	P2 - PressureDrop2	P3 - PressureDrop3	P4 - PressureDrop4
2						Pa	Pa	Pa	Pa
3	Current	4	4	4	4	12892	11366	13028	16619
4	DP 1	3	3	3	3	12882	11247	13487	16731
5	DP 2	2	2	2	2	12897	11546	13554	16911
6	DP 3	1	1	1	1	13403	11477	13920	17666
7	DP 4	0	0	0	0	13555	11750	13967	17718
8	DP 5	-1	-1	-1	-1	14057	11860	14506	18044



Balanced flow and 8% less pressure drop

Thermal fatigue of a valve



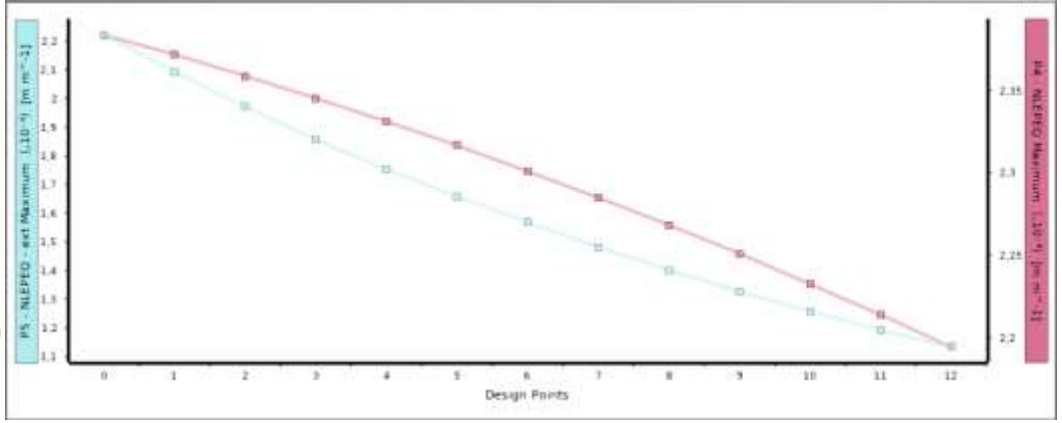


NLEPEQ value substantially decreased (**-49%**)

Table of Design Points

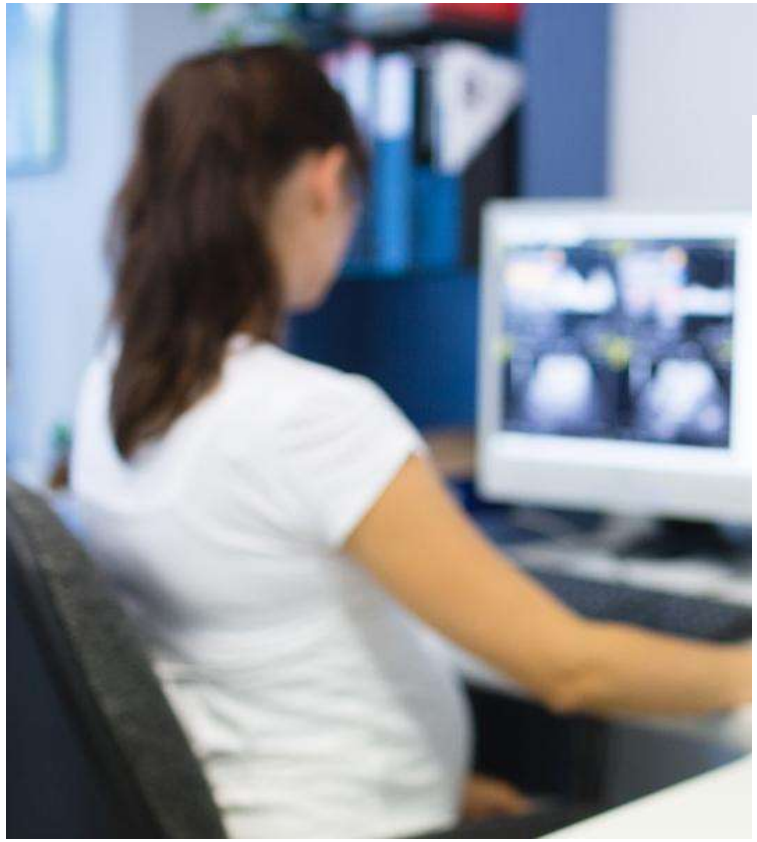
	A	B	C	D	E	F	G	H	I	J
1	Name	Update Order	P1 - RBF Morph Set Up Shape ID	P2 - SEQV Maximum	P3 - SEQV - ext Maximum	P4 - NLEPEQ Maximum	P5 - NLEPEQ - ext Maximum	Ret...	Retained Data	Note
2	Units			Pa	Pa	m m^-1	m m^-1			
3	DP 0 (Current)	1	0	1,5402E+08	5,363E+07	0,0023835	0,00022191	✓	✓	
4	DP 1	2	1	1,5425E+08	5,398E+07	0,0023718	0,00020926	✓	✓	
5	DP 2	3	2	1,5325E+08	5,2605E+07	0,0023588	0,00019708	✓	✓	
6	DP 3	4	3	1,5285E+08	5,25E+07	0,0023452	0,00018557	✓	✓	
7	DP 4	5	4	1,5240E+08	5,2377E+07	0,0023311	0,00017529	✓	✓	
8	DP 5	6	5	1,5266E+08	5,2267E+07	0,0023166	0,00016586	✓	✓	
9	DP 6	7	6	1,5293E+08	5,2144E+07	0,0023008	0,00015691	✓	✓	
10	DP 7	8	7	1,5322E+08	5,2022E+07	0,0022849	0,00014824	✓	✓	
11	DP 8	9	8	1,535E+08	5,1888E+07	0,0022683	0,00014026	✓	✓	
12	DP 9	10	9	1,5378E+08	5,1748E+07	0,0022509	0,00013278	✓	✓	
13	DP 10	11	10	1,5407E+08	5,1598E+07	0,0022324	0,00012589	✓	✓	
14	DP 11	12	11	1,5435E+08	5,1443E+07	0,0022139	0,00011936	✓	✓	
15	DP 12	13	12	1,5463E+08	5,1265E+07	0,0021941	0,00011347	✓	✓	
*										

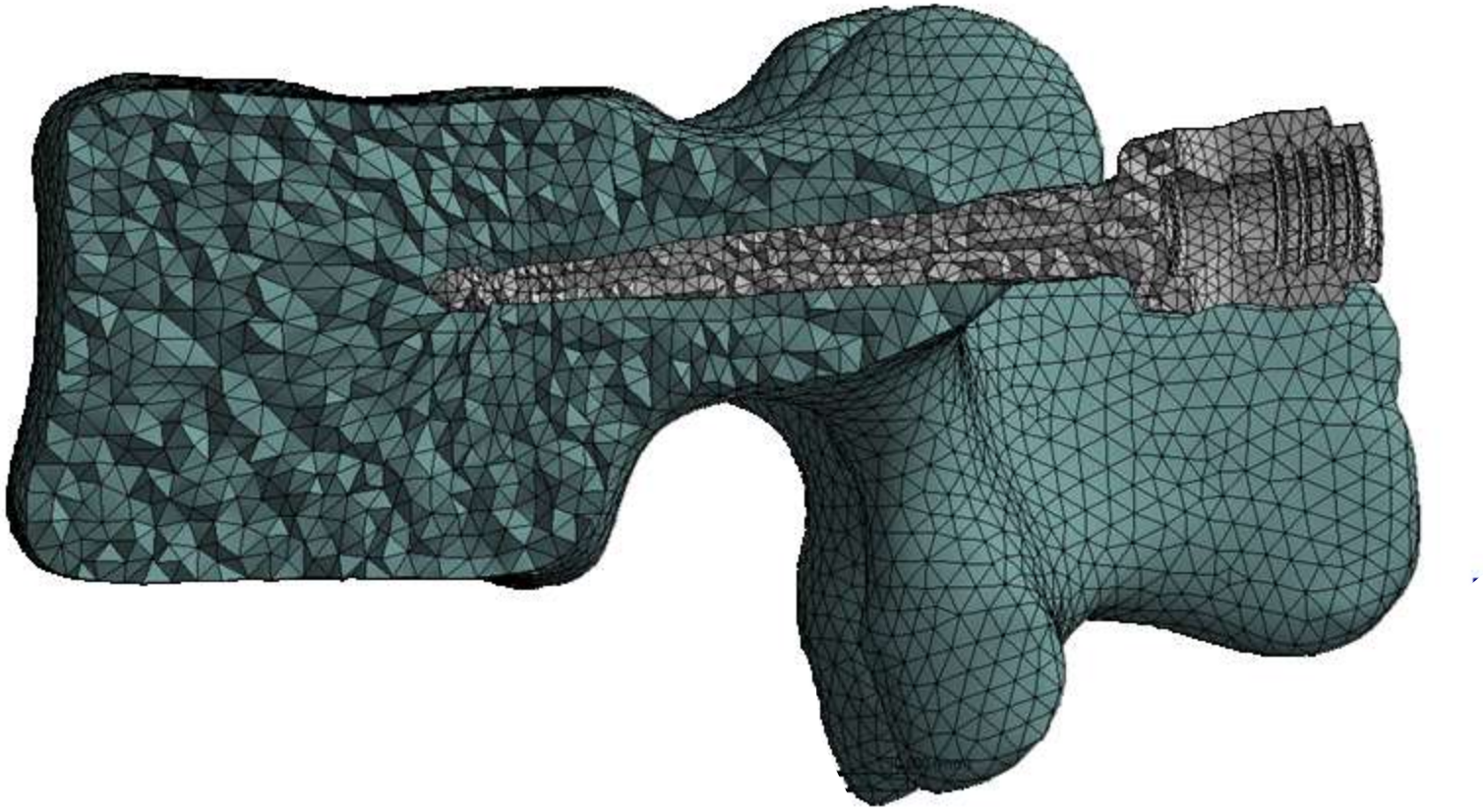
Parameter Chart 0



Spine surgery Digital Twin

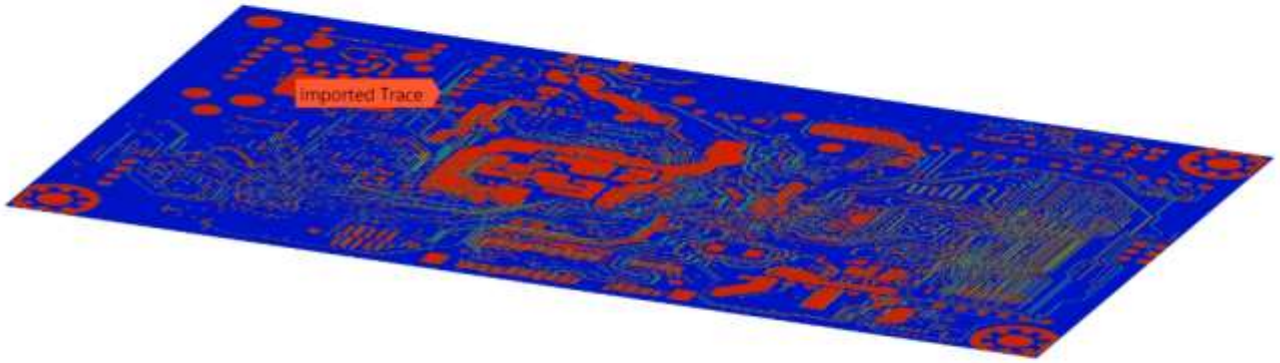
spinner
next generation spine experts

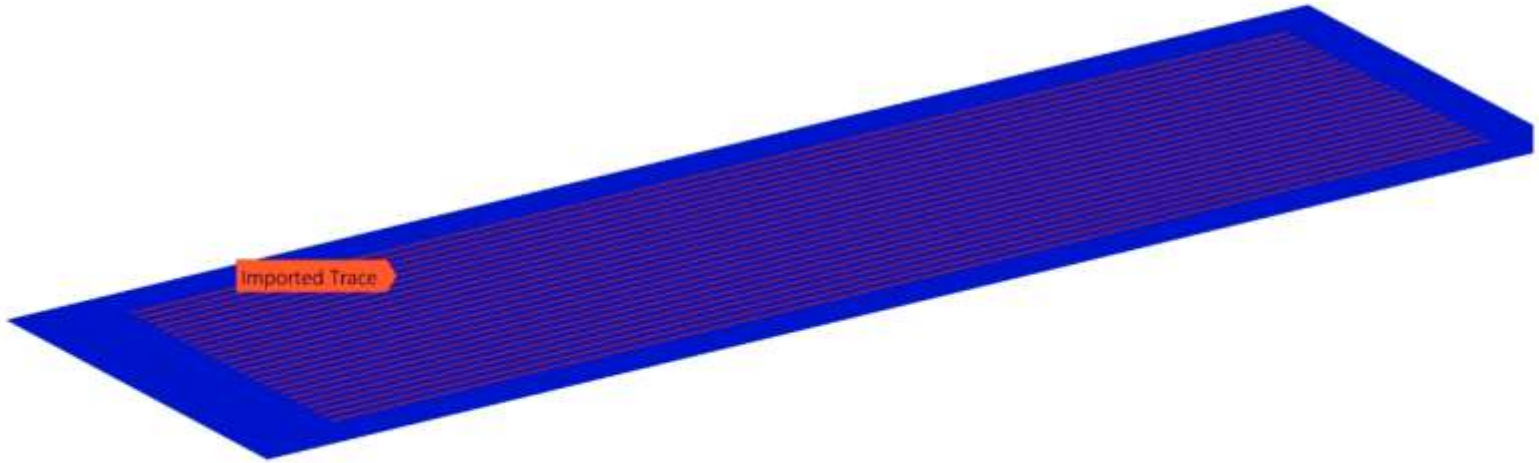




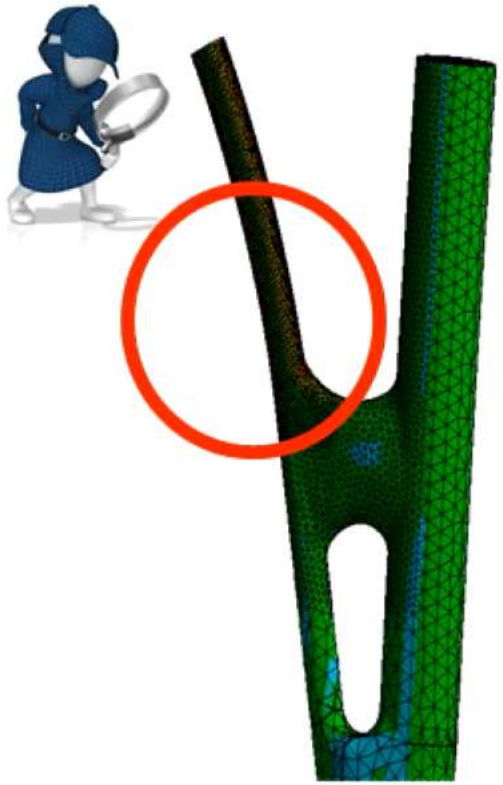
Morph onto CAD shapes

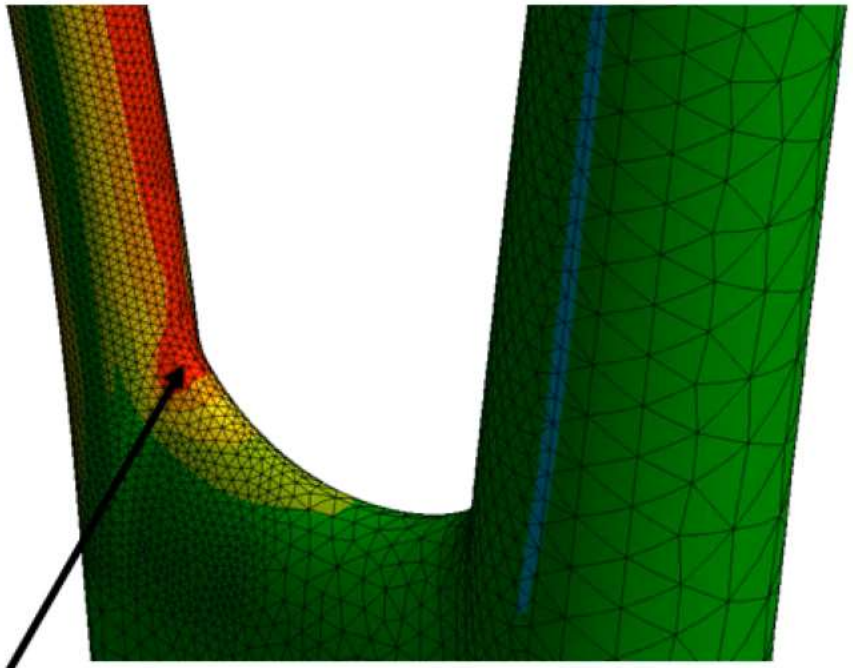
RBF Morph & Ansys Mechanical allow fast adaption of Flexible PCBs onto the installation shape





Parameter less shape optimization

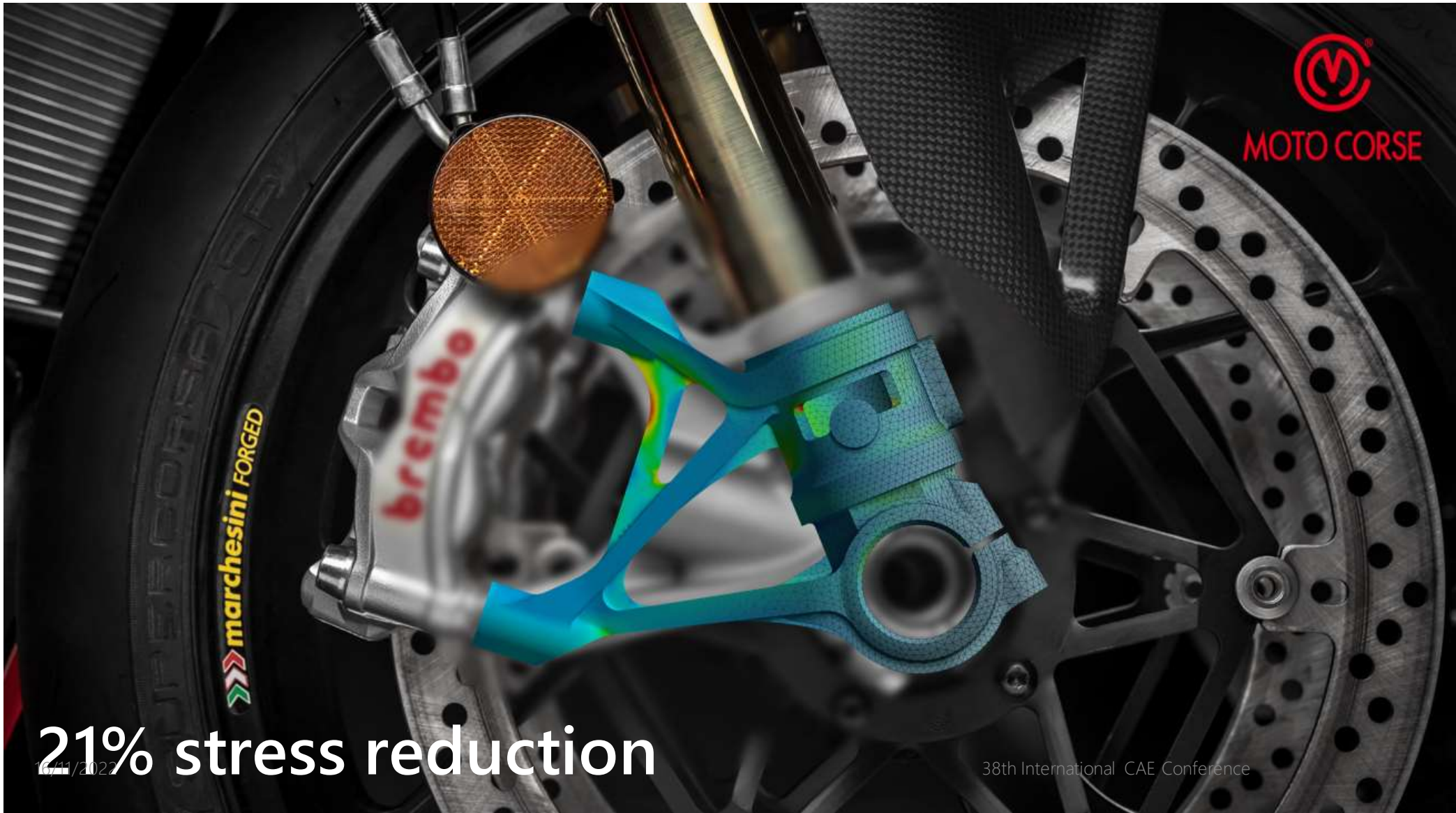




$\overline{\sigma_{VM}} = 1{,}749\ MPa$

$\max \sigma_{VM} = 12{,}079\ MPa$

Structural Optimization of a wheel hub

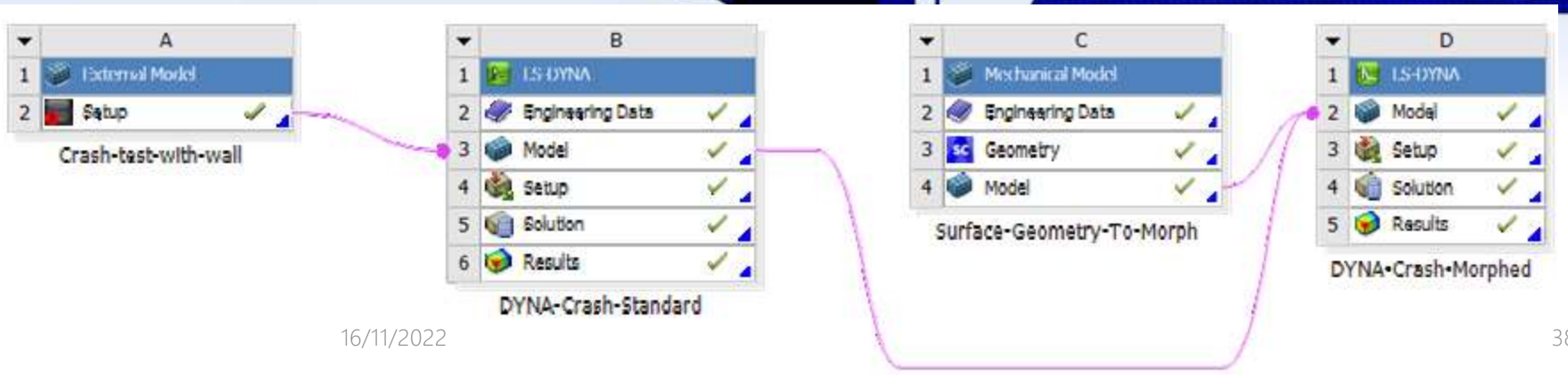


21% stress reduction

Reuse the LS-DYNA model of a different car!

CRASH TEST: STARTING MODEL

CRASH TEST: MORPHED MODEL



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