SIMULATIONSUMMIT connect

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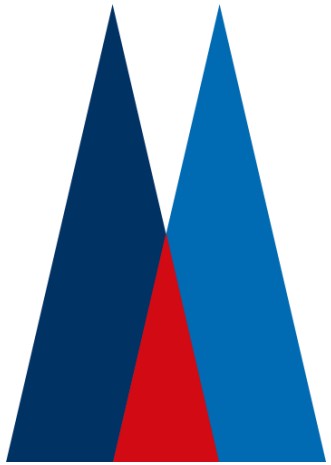

Advanced radial basis function mesh morphing of RBF Morph for LS-DYNA enabled in Ansys Mechanical.

TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

rbf™

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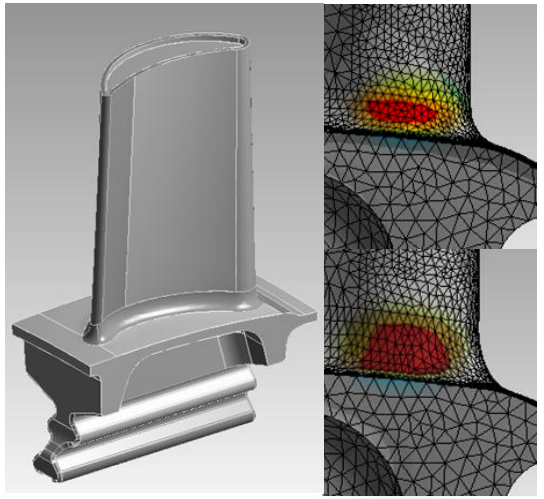
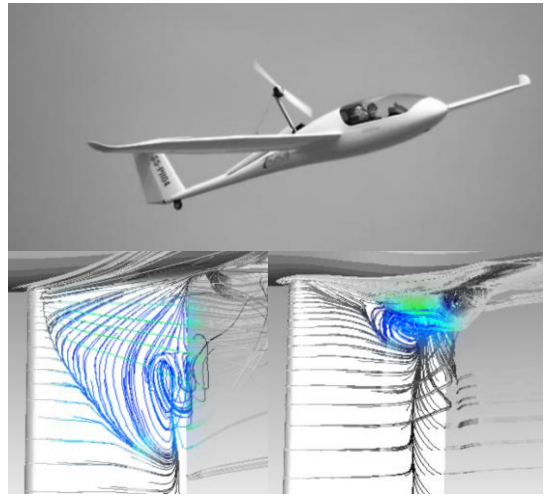
Outline

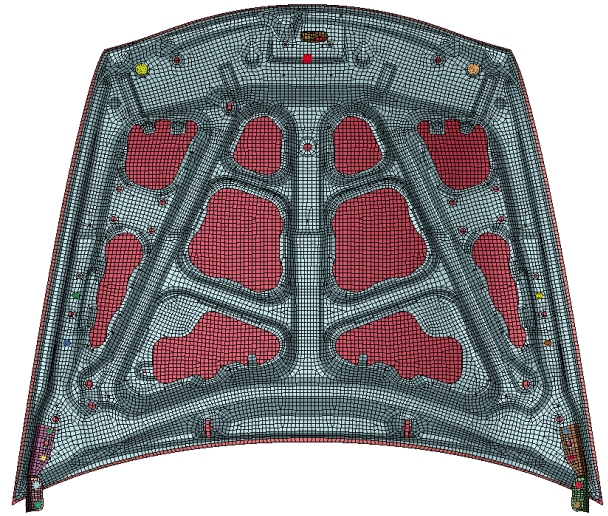
- RBF Morph technology and software solutions for **shape optimization**
- Mesh morphing needs for **crashworthiness** in the automotive industry
- A workflow based on **LS-DYNA** solver, Ansys Mechanical and RBF Morph
- Industrial example: exploring how a **car bonnet** can be reshaped
- Conclusions



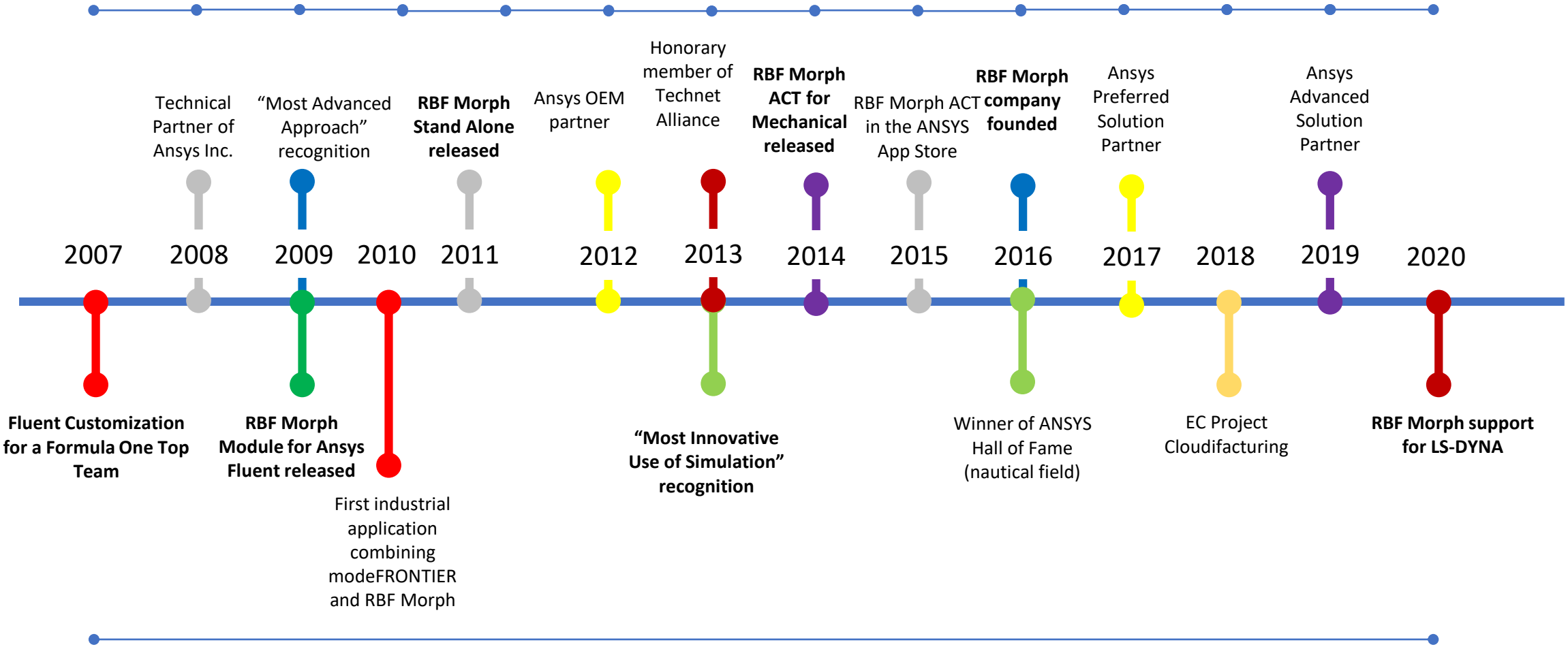


Ansys

LS-DYNA



10+ years of RBF Morph



Industries served (100+ institutions)

Automotive

Aerospace & Defence

Nautical & Marine

Healthcare & Medical

Energy

Oil & Gas

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

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

Biancolini, M. E. (2017). *Fast radial basis functions for engineering applications*. Springer International Publishing.

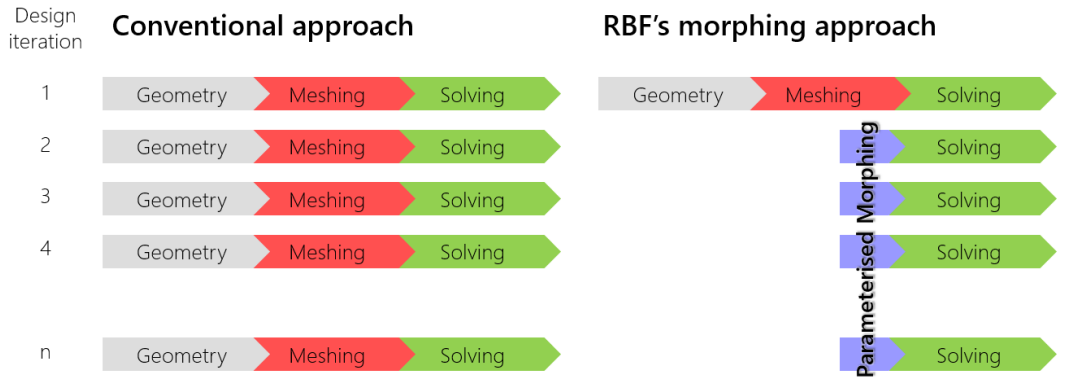
Parametric CAE models

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.

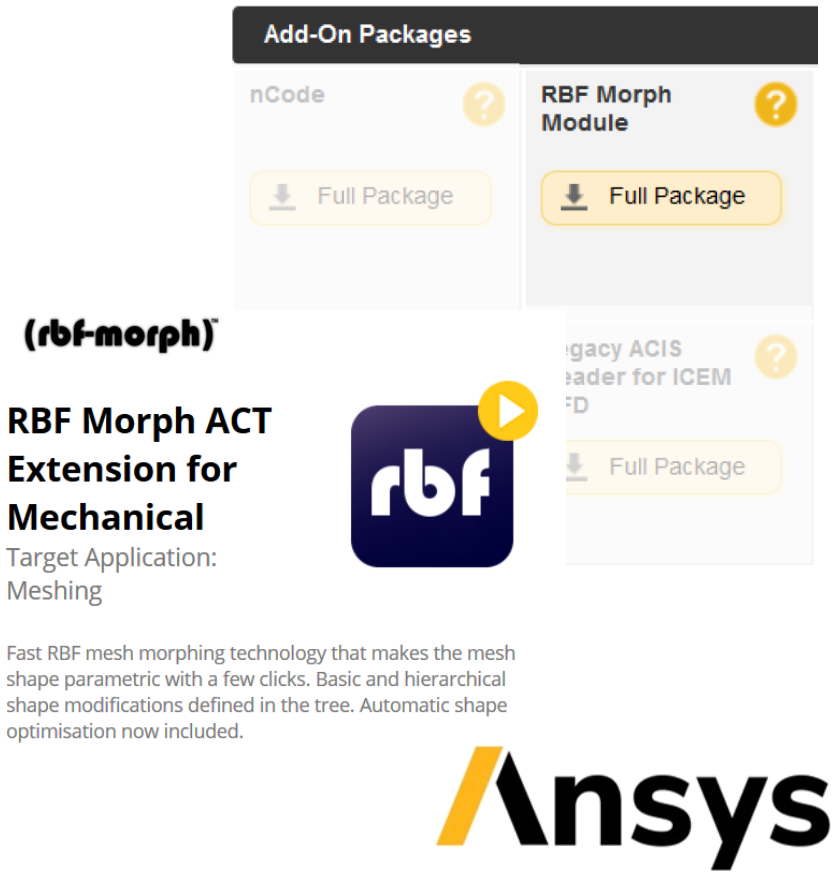


- It's **easy and fast**: shape parameters are defined in the CAE GUI. No need to iterate the CAD
- The turnaround time of the optimization is usually **reduced by a factor five** (weeks become days)

We offer Ansys integrated solutions…

ACT Extension (FEM)

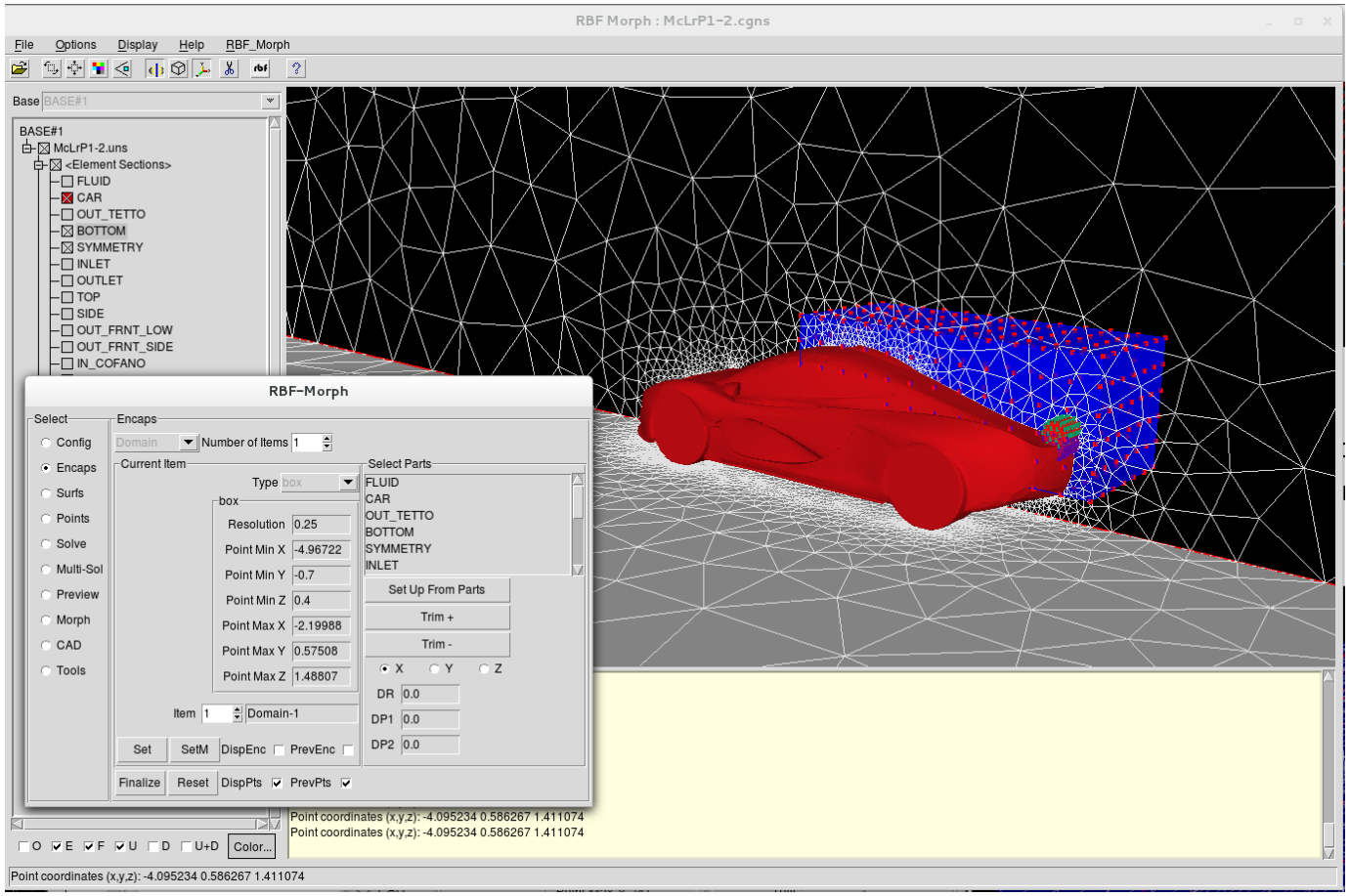
- Released in **2014**
- Fully embedded in ANSYS **Mechanical** (parametric)
- Benefits of **underlyi geometry** (or aux ge with dead meshes)
- …**WB** Meshing



Fluent Module (CFD)

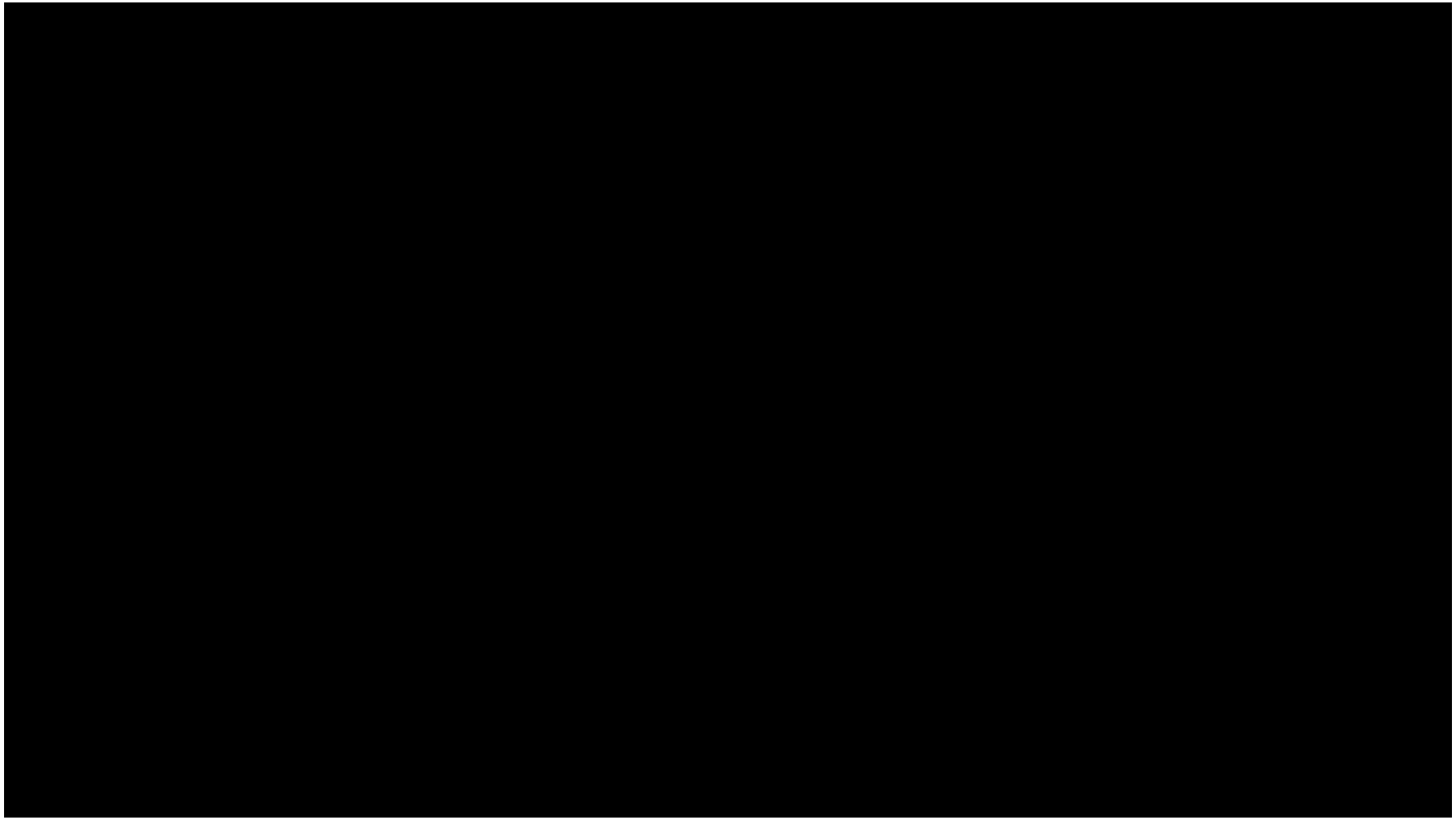
- Released in **2009**
- Fully integrated within Fluent (GUI, TUI & solving stage), Workbench and **Adjoint Solver**
- Multi physics features (**FSI**)

…and a Stand Alone software



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

Some examples of mesh morphing for mechanical applications



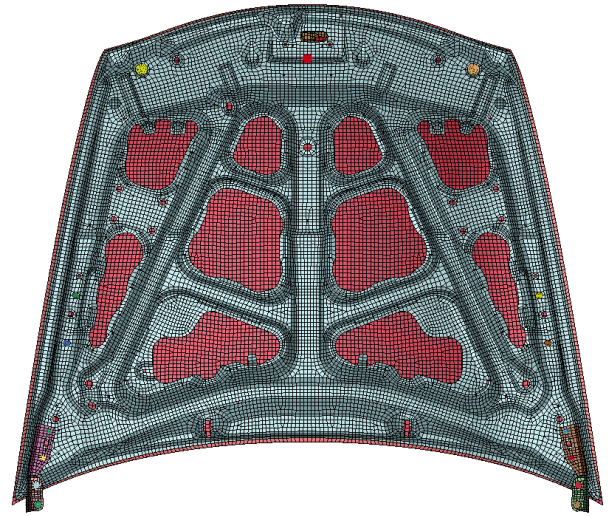
https://youtu.be/Txd6gvkhko0

Mesh morphing needs in the automotive industry

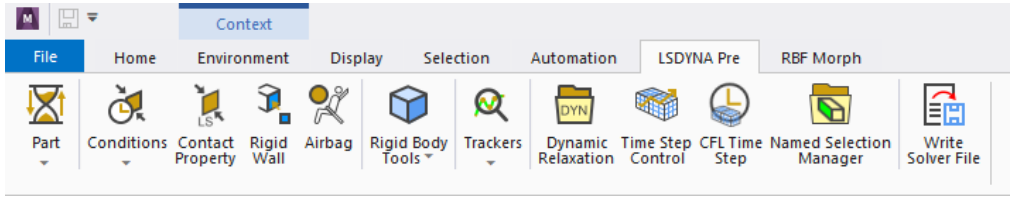
- Explore **shape variants** without recreating a new model
- **Reuse** the FEA model of a similar car at early stage design of a new car
- Mesh morphing requirements
  - Perfect matching between **style surface** and morphed FEM
  - Same platform (hinges, connections).
  - Keep same cross section
  - Geometrical constraints (preserve welding)
  - Discontinuities are not acceptable

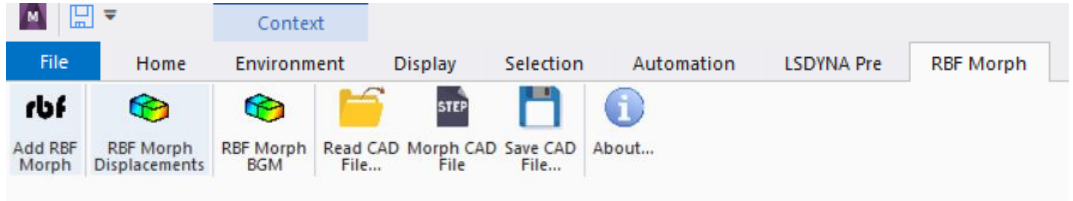
Ansys

LS-DYNA



Combined usage of both the ACTs





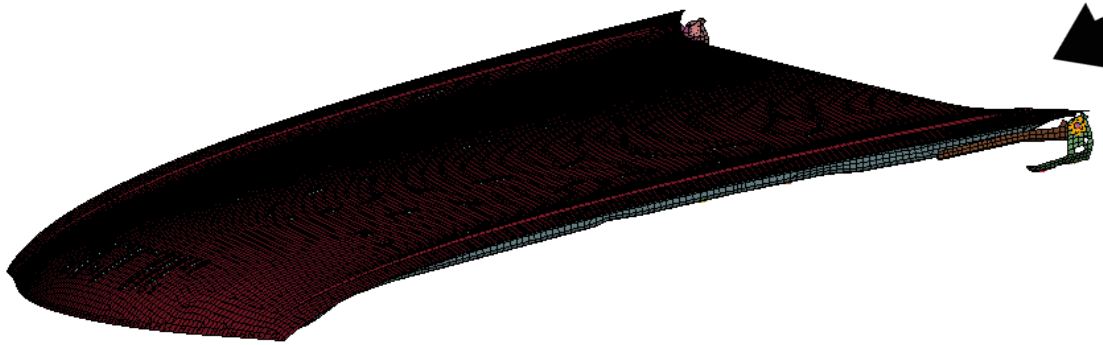
- Direct shape changes within the Ansys Workbench Environment
- Ability to quickly edit LS-DYNA keyword files
- Flexible and easy to use with a consistent ANSYS-like user interface

Demonstration case of a car bonnet

Honda Accord 2011 model

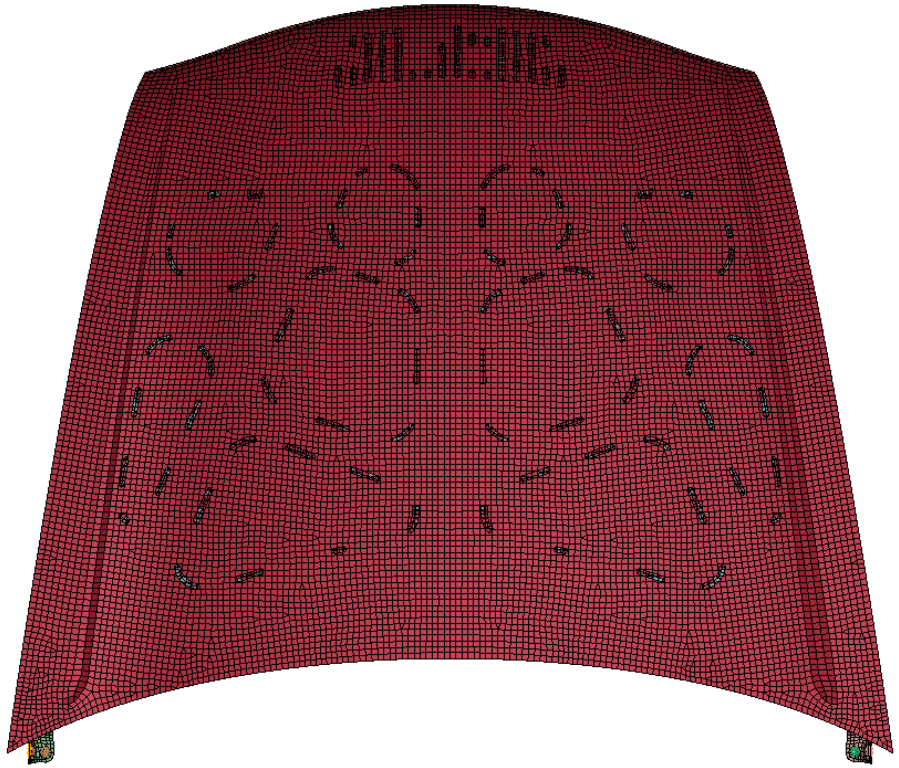
https://www.nhtsa.gov/crash-simulation-vehicle-models

- Starting from a LS-DYNA keyword file

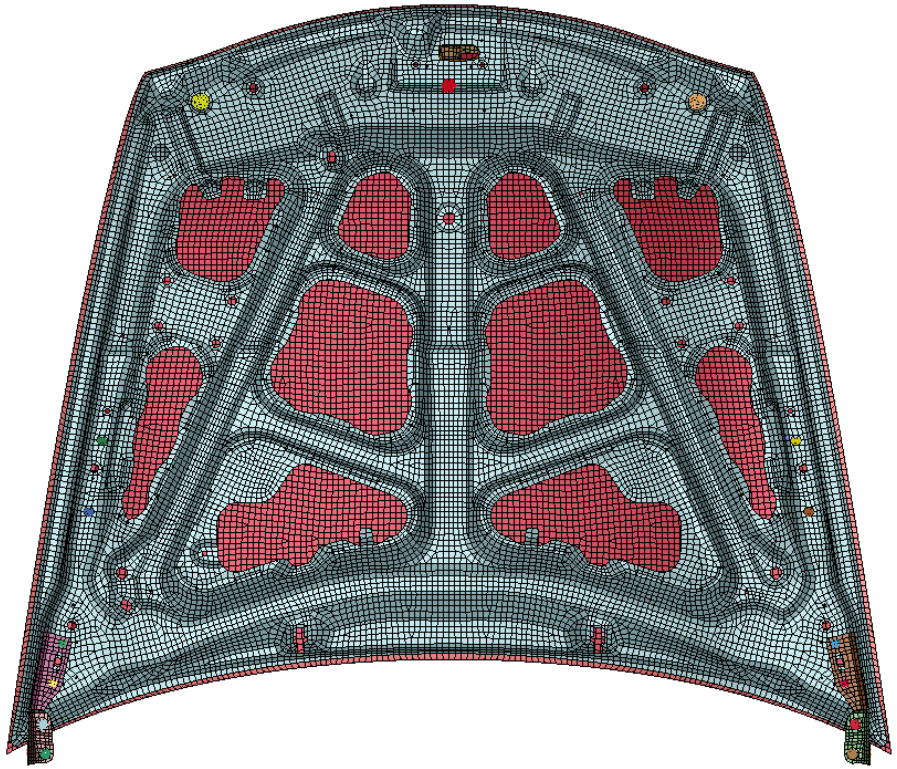


N° Elements: 38952
N° Nodes: 41979

Solid elements: 1440
Surface elements: 37512

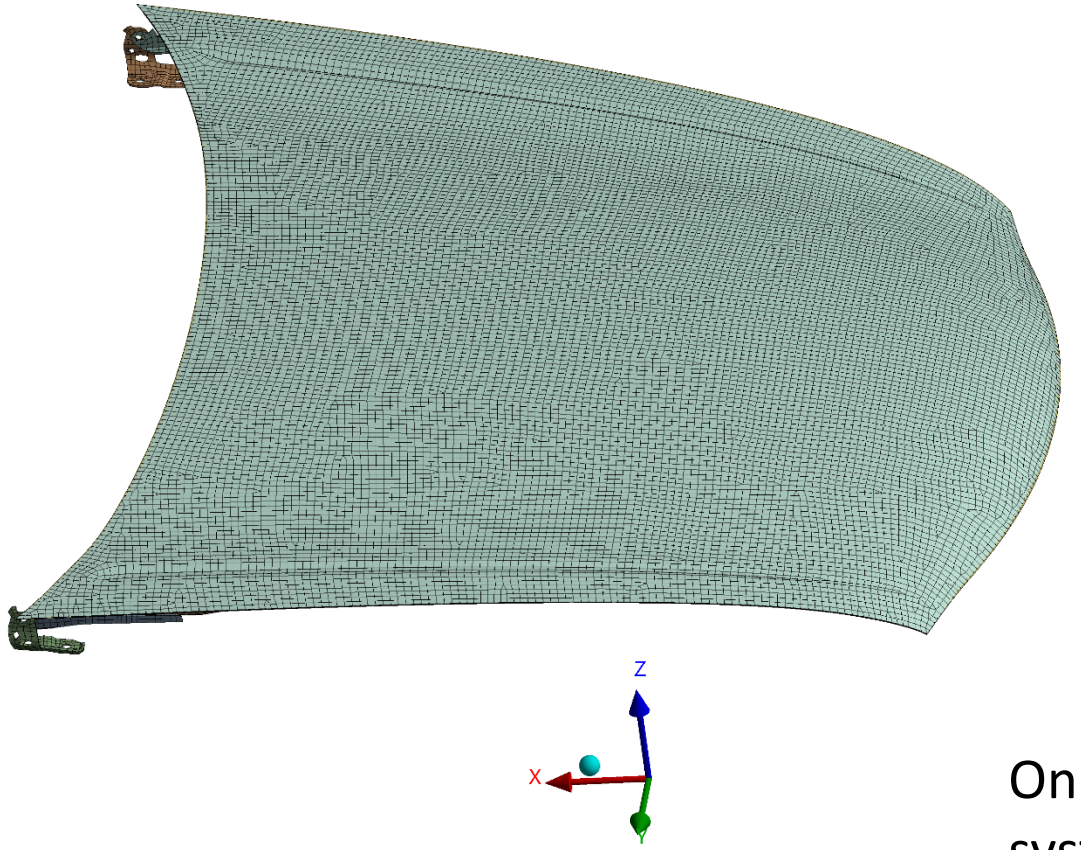


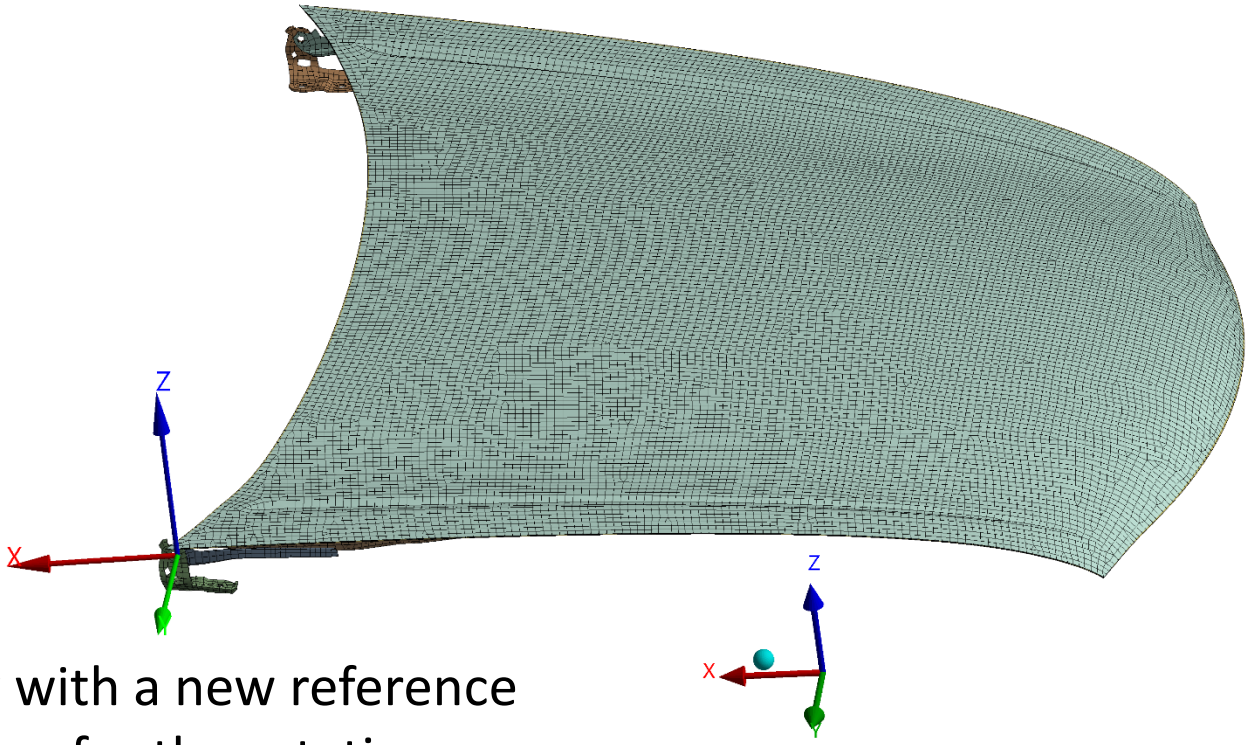
3 Solid body
11 Surface Body



But what we can do with our LS-DYNA model?

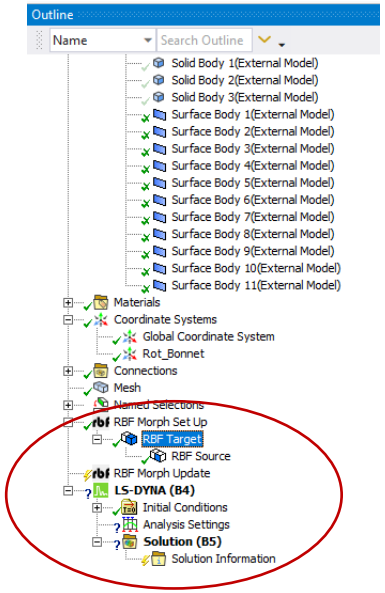
- **We can open our bonnet…**

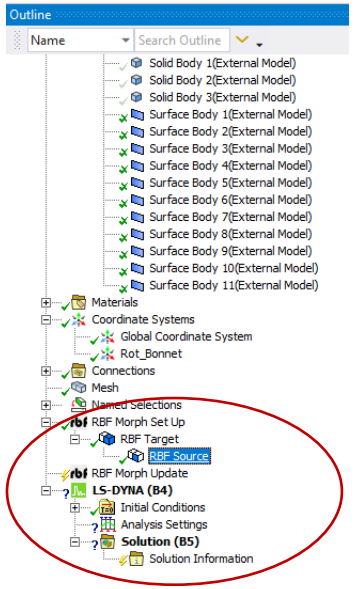




Only with a new reference system for the rotation…

All in LS-DYNA-Workbench environment!



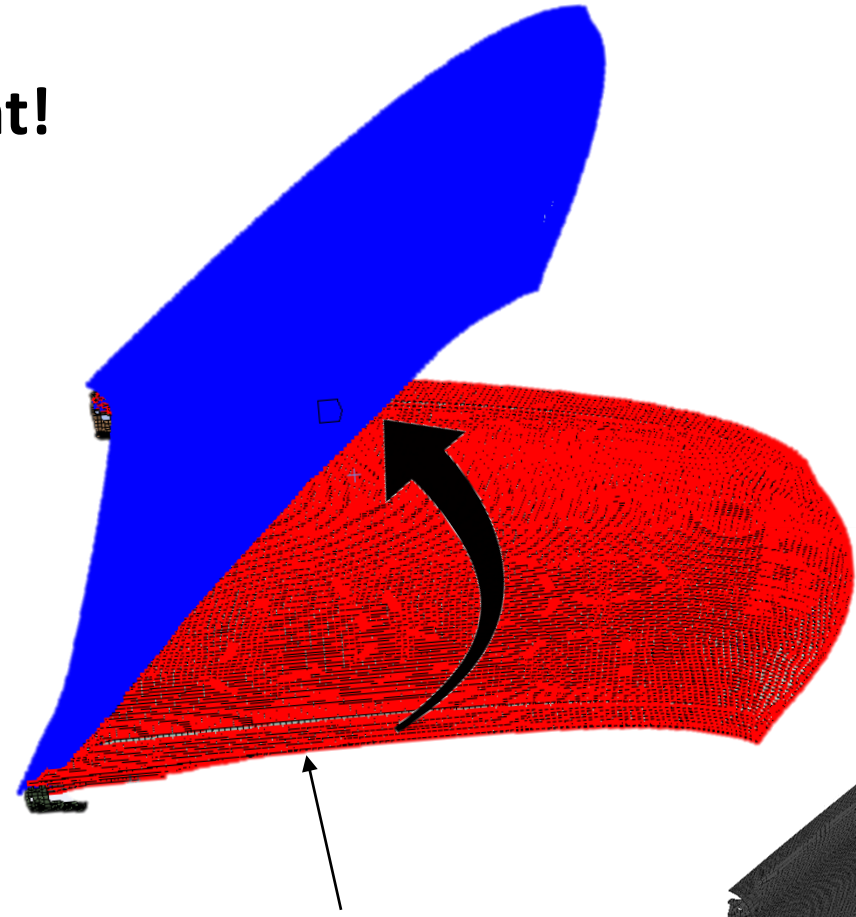


Details of "RBF Target"

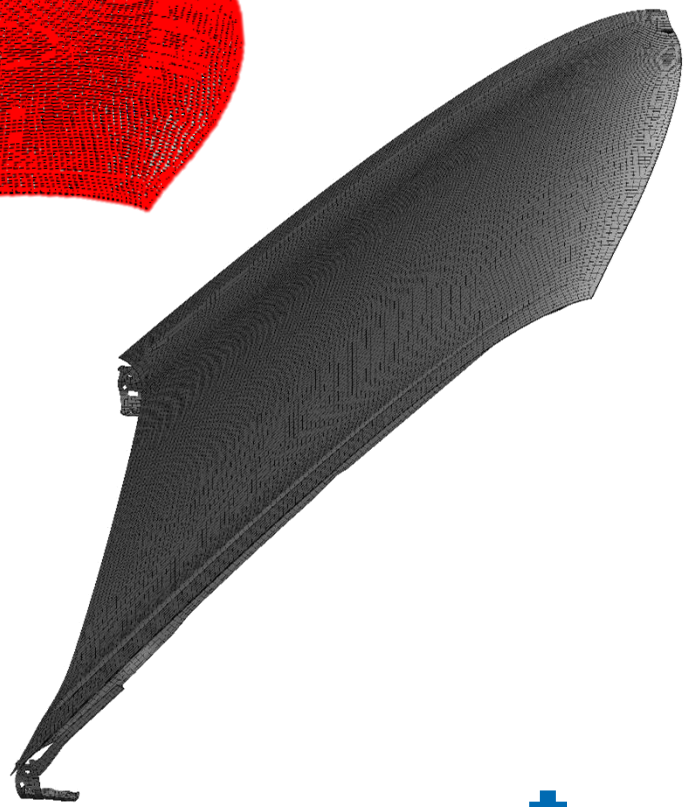
Node Selection	
Scoping Method	Geometry Selection
Geometry	12 Bodies
General	
Transformation	Translation
Translation Definition	Manual
Delta x	0 m
Delta y	0 m
Delta z	0 m
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No
RBF Problem	
Source	38473
Target	42655

Details of "RBF Source"

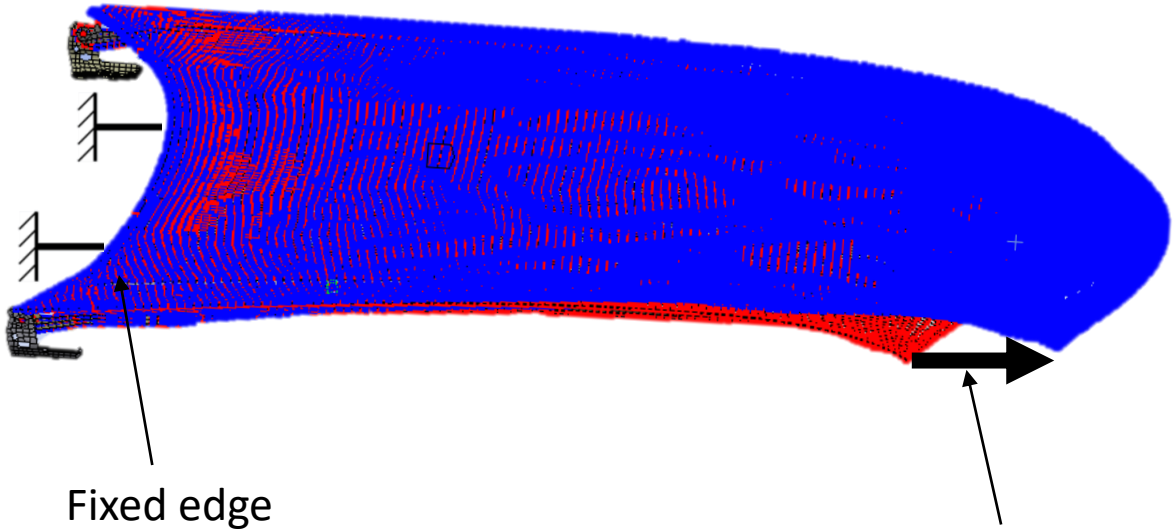
Node Selection	
Scoping Method	Geometry Selection
Geometry	16 Faces
General	
Transformation	Rotation
Rotation System Definition	By Coordinate System
Angle	45 °
Coordinate System	Rot_Bonnet
Axis Used	y
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No
RBF Problem	
Source	0
Target	38473

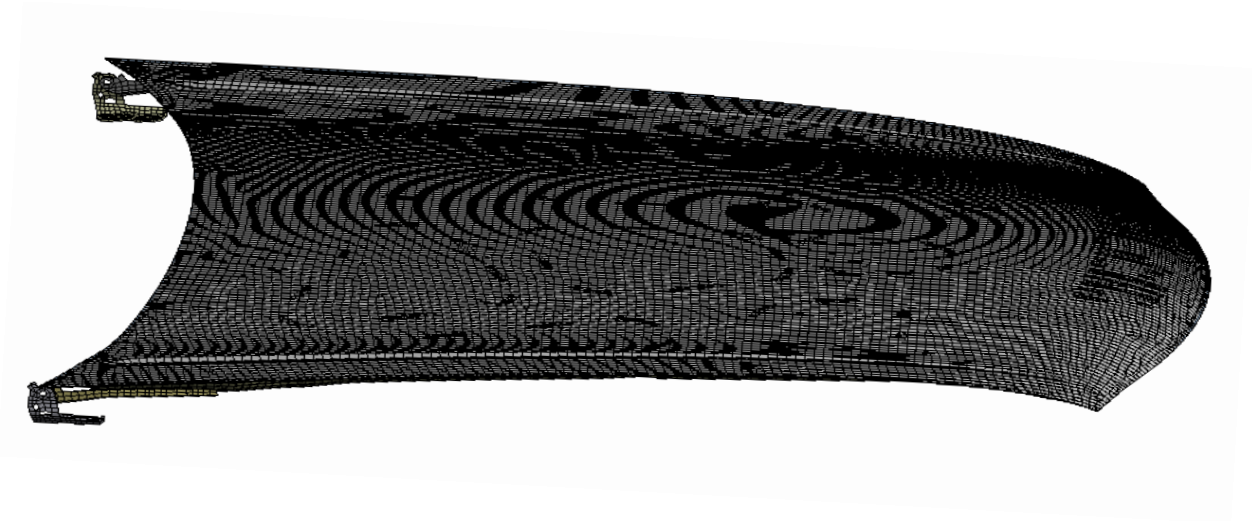


Moving surface: rotation

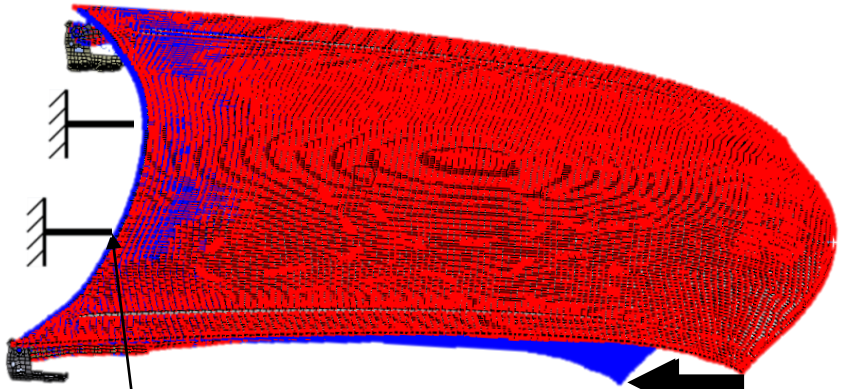


- **We can stretch it preserving its supporting bodies !**



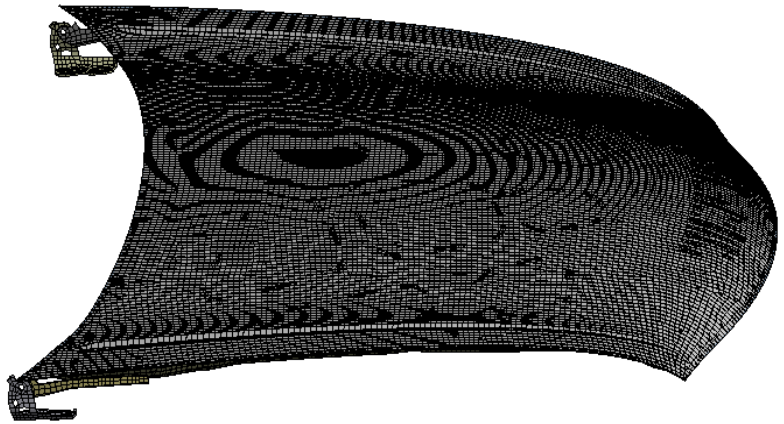


- **In an instant, we can narrow it down a lot!**

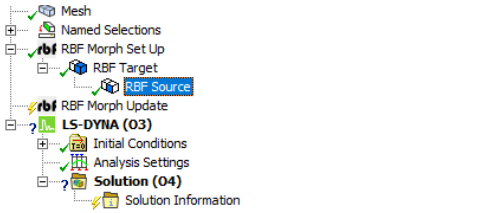


Fixed edge

Moving edge: translation

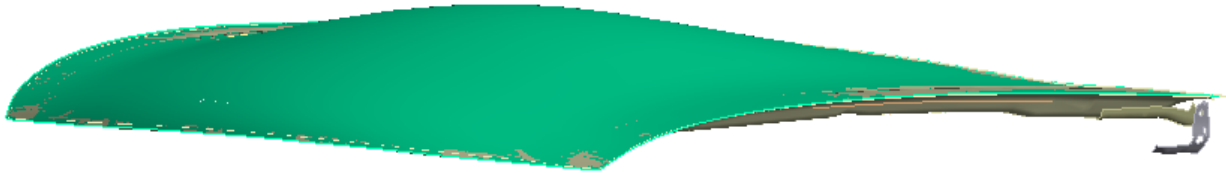


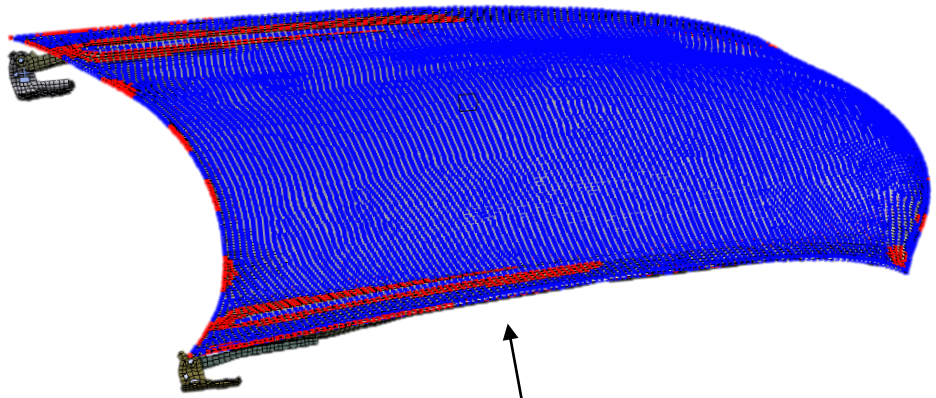
- **We can change the shape of the bonnet altering its concavity using a similar geometric model!**



Details of "RBF Source"

Node Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
General	
Transformation	Surface Targeting
Percentage	1
Targeting behaviour	Along Target Normal
Geometry Selection	
Scoping Method	Geometry Selection
Geometry	1 Face
RBF Function	
Degree	1
Combine Select	
Acting On	Undeformed
If Selected Nodes Overlap	Override
Coord Filtering	No

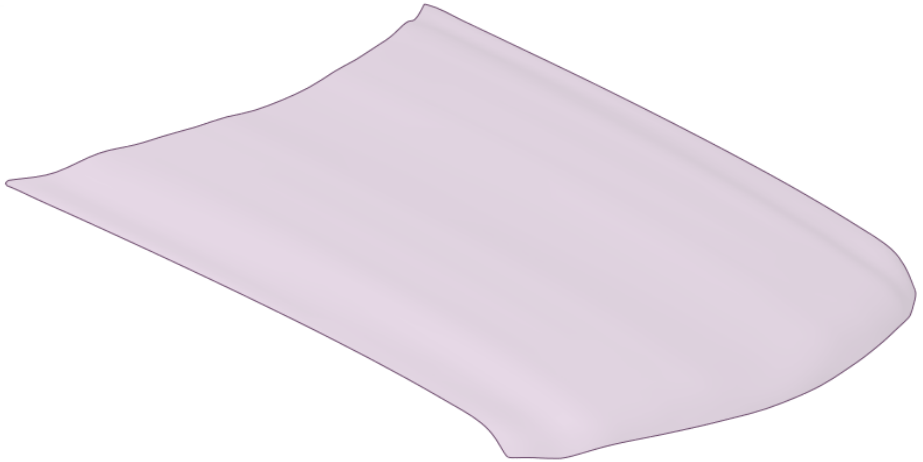


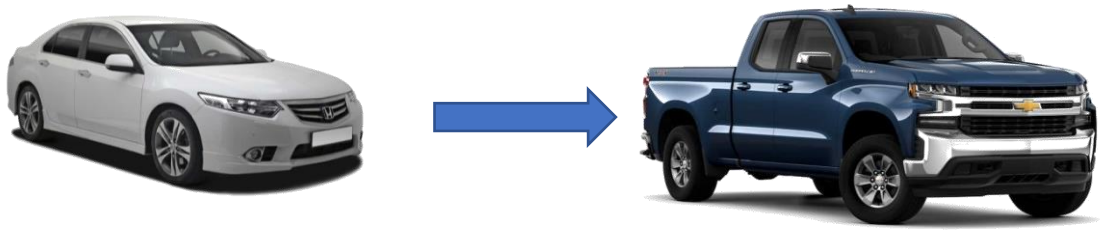


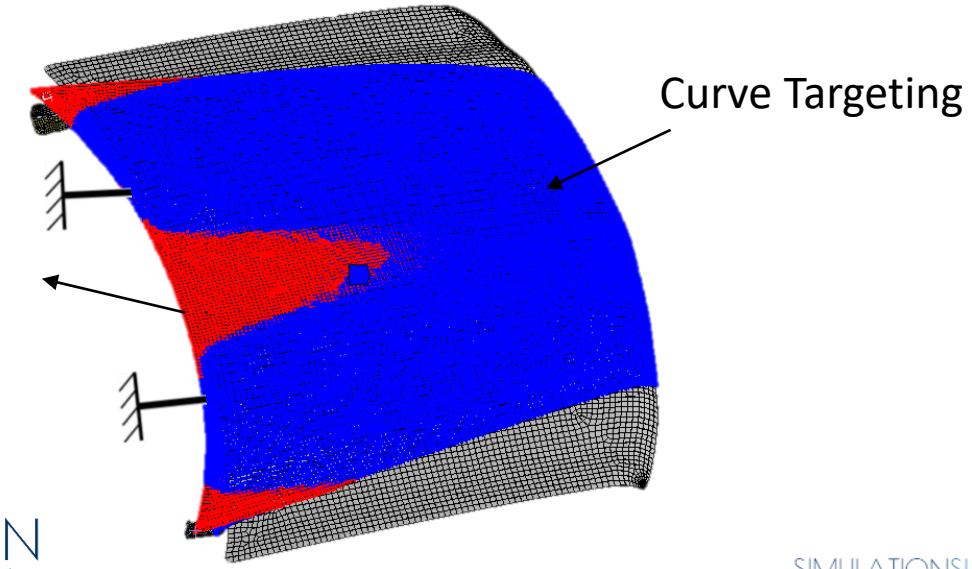
Surface Targeting

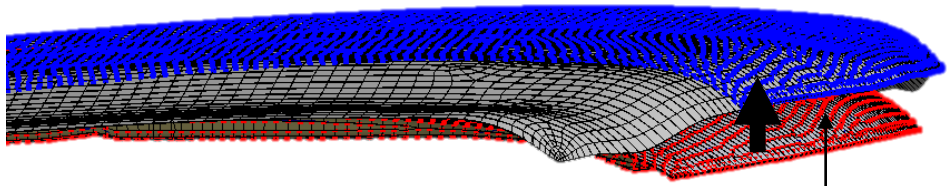
Obviously preserving the quality of the mesh…

- **We can also modify our model using a totally different one!!!**



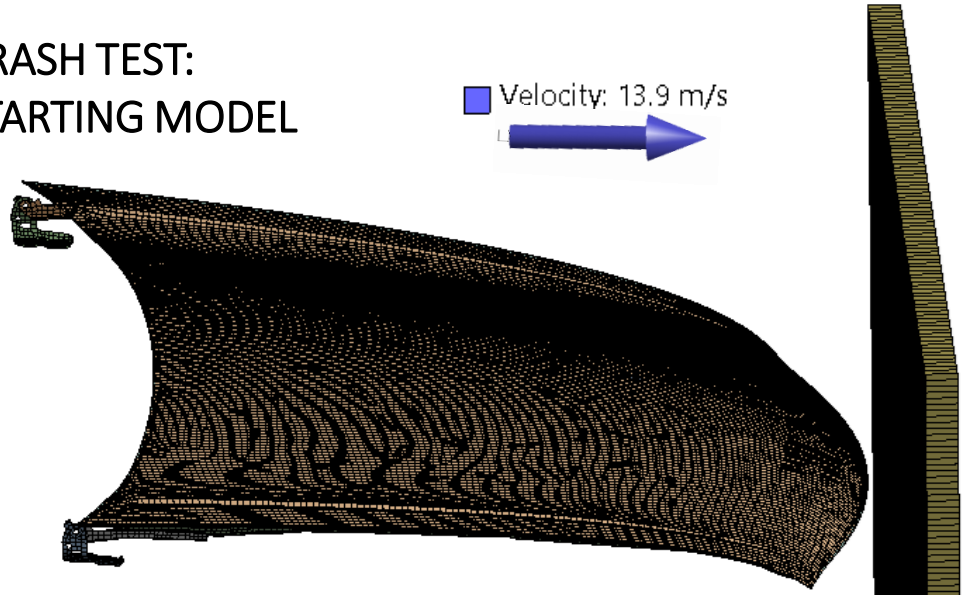




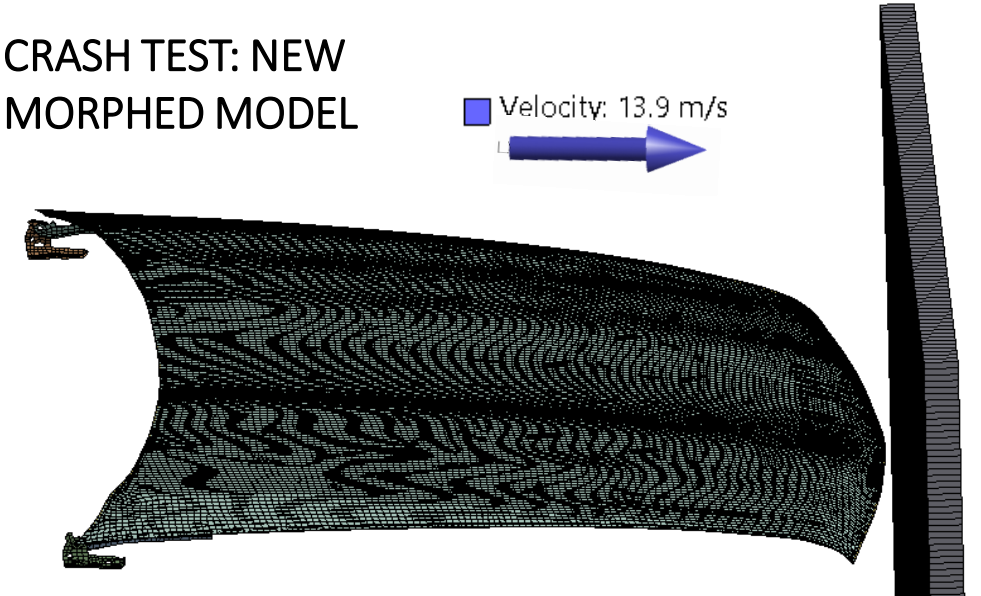


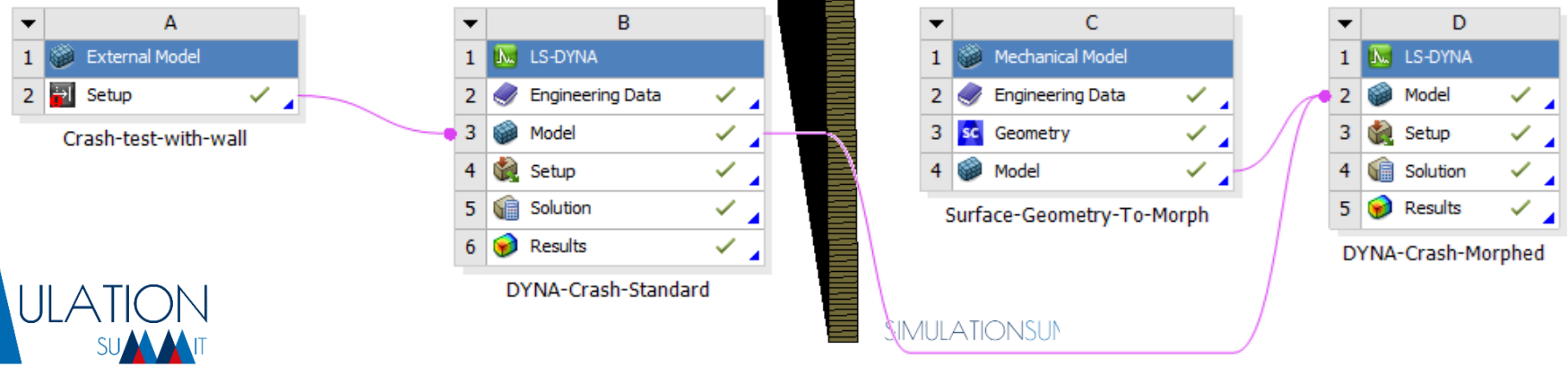
- **Everything to have a model ready to be run through LS-DYNA**

CRASH TEST:
STARTING MODEL

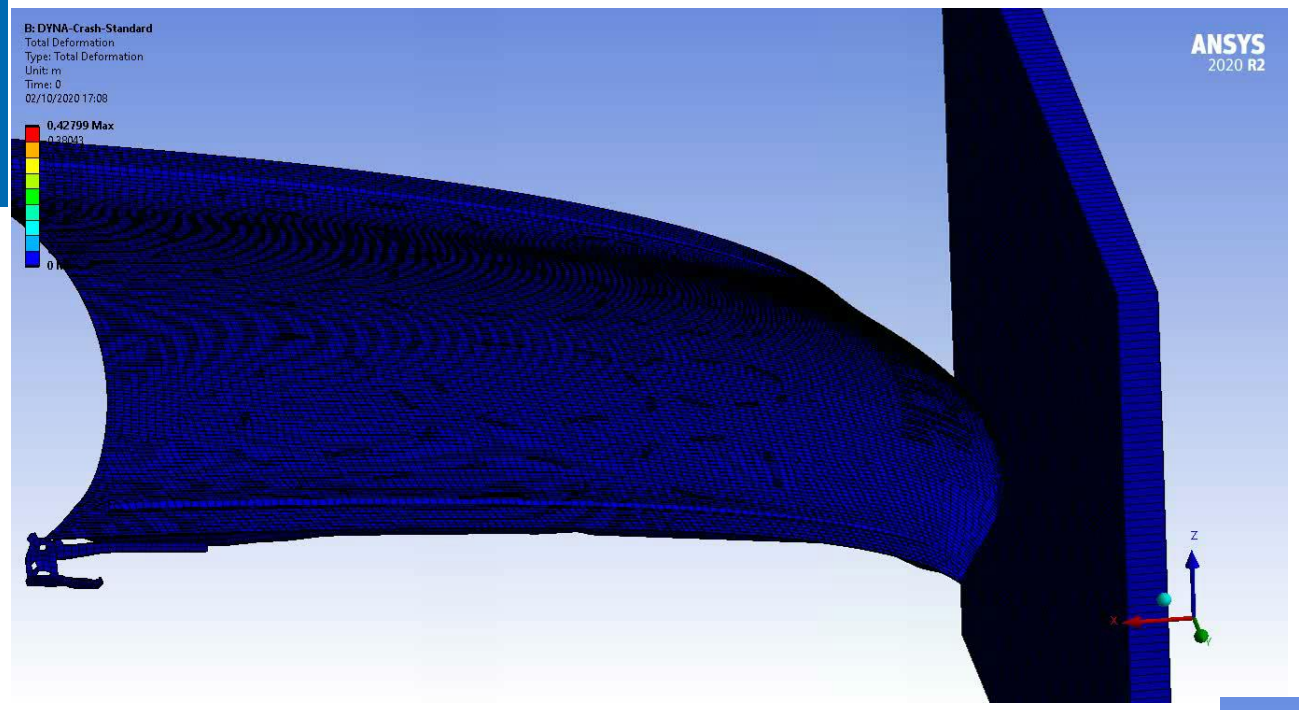


CRASH TEST: NEW
MORPHED MODEL



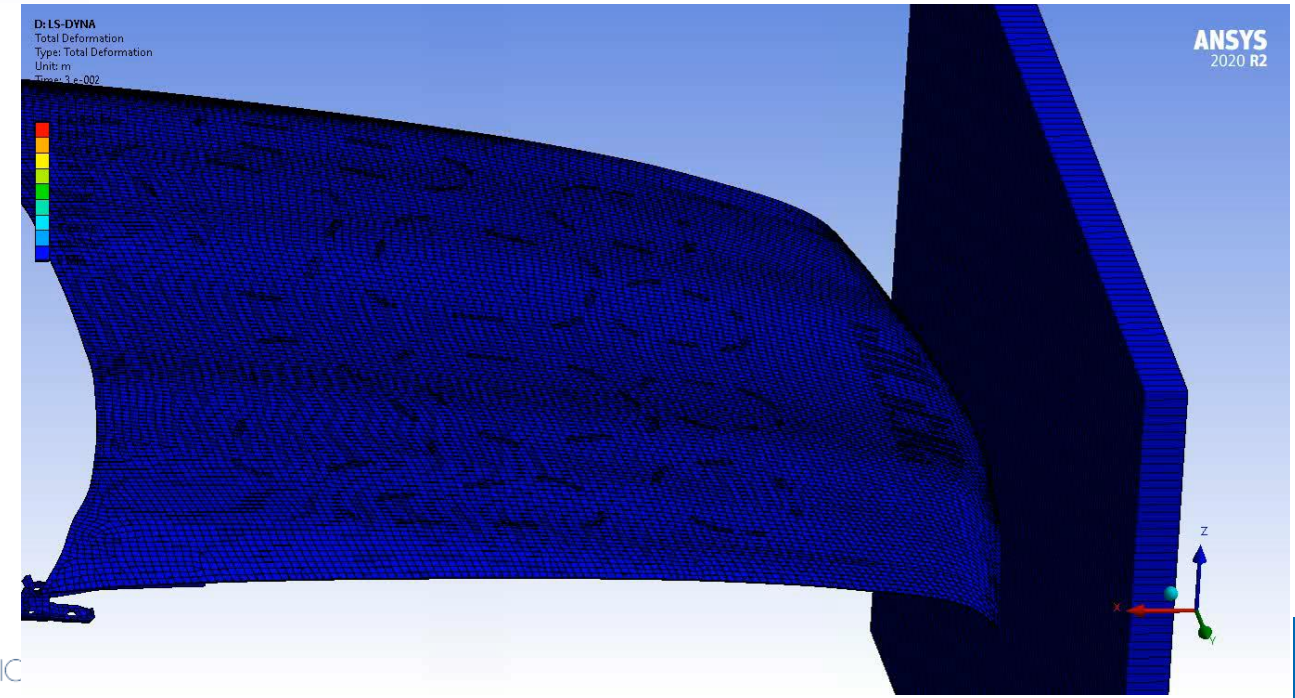


Example of results



CRASH TEST:
STARTING MODEL

CRASH TEST: NEW
MORPHED MODEL

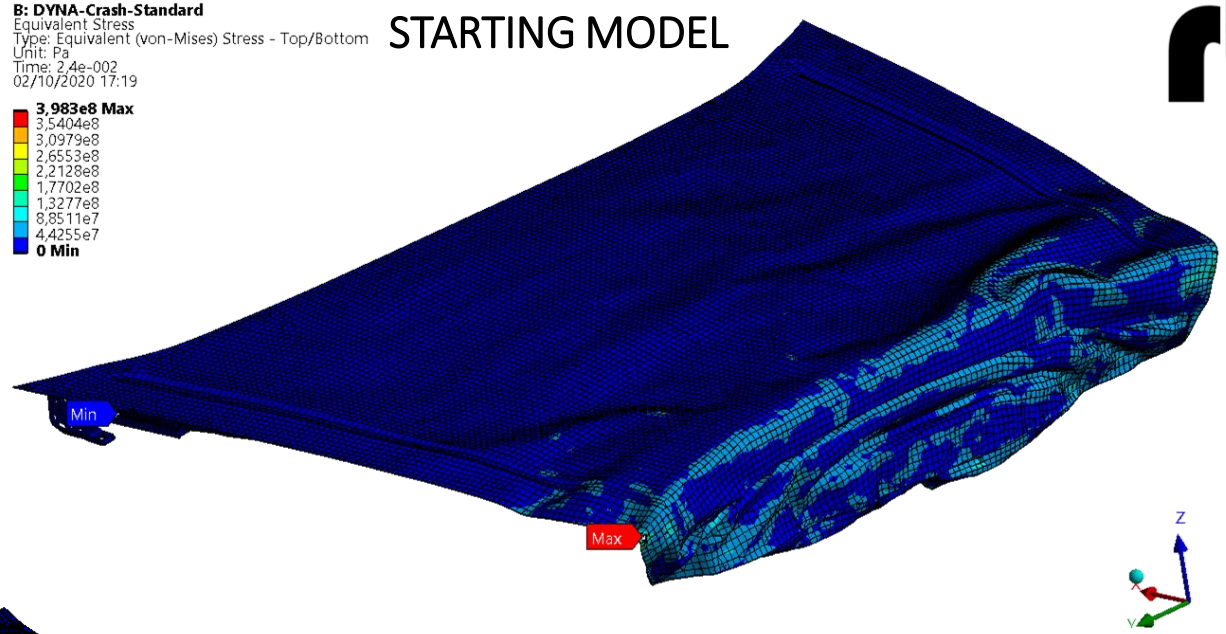


CRASH TEST: STARTING MODEL

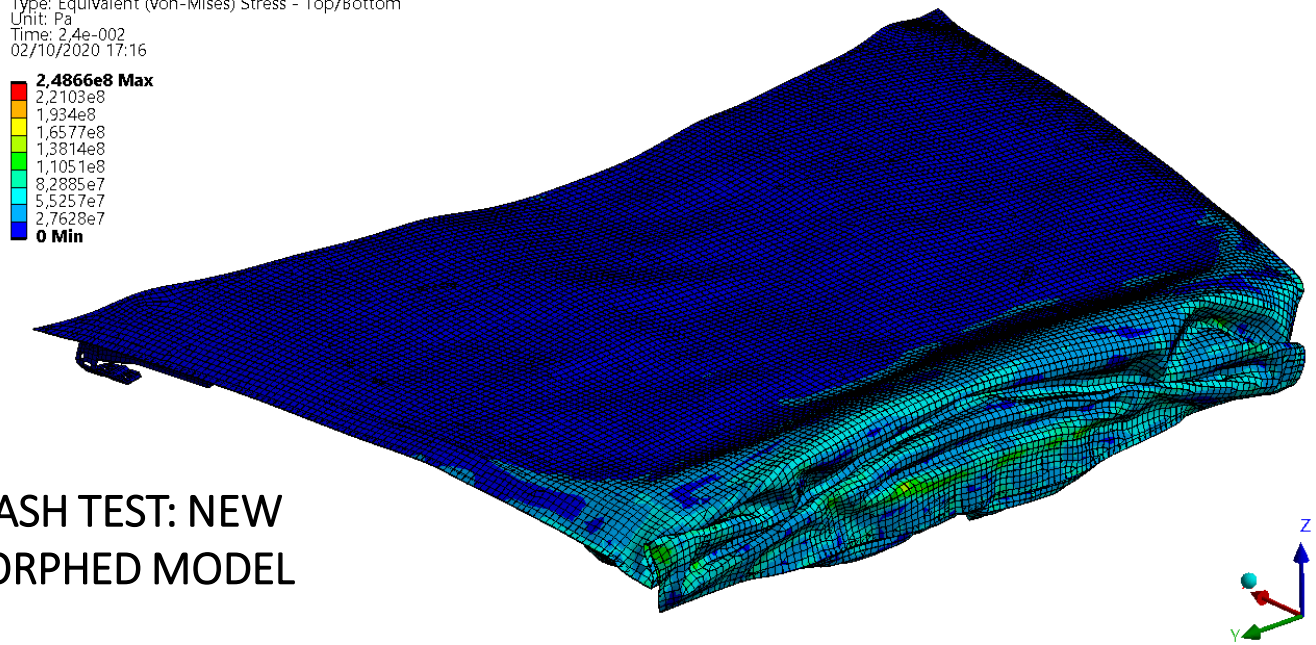
Tabular Data

	Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1	0,	0,	0,	0,
2	1,4998e-003	0,	5,143e-003	2,5526e-005
3	2,9999e-003	0,	9,8229e-003	5,0075e-005
4	4,4999e-003	0,	1,9467e+008	1,9668e+006
5	5,9999e-003	0,	1,5395e+008	4,9243e+006
6	7,4998e-003	0,	1,939e+008	7,7296e+006
7	8,9997e-003	0,	2,1228e+008	8,8496e+006
8	1,05e-002	0,	1,7293e+008	9,8961e+006
9	1,2e-002	0,	2,0188e+008	1,097e+007
10	1,35e-002	0,	1,8492e+008	1,2002e+007
11	1,5e-002	0,	1,9425e+008	1,2555e+007
12	1,65e-002	0,	1,9891e+008	1,3365e+007
13	1,8e-002	0,	2,4182e+008	1,3884e+007
14	1,95e-002	0,	2,7727e+008	1,421e+007
15	2,1e-002	0,	2,5734e+008	1,4699e+007
16	2,25e-002	0,	2,5201e+008	1,5491e+007
17	2,4e-002	0,	3,983e+008	1,6183e+007
18	2,55e-002	0,	3,1898e+008	1,658e+007
19	2,7e-002	0,	4,066e+008	1,7061e+007
20	2,85e-002	0,	2,6124e+008	1,752e+007
21	3,e-002	0,	3,023e+008	1,7826e+007
22	3,e-002	0,	3,023e+008	1,7826e+007

MAX



CRASH TEST: NEW MORPHED MODEL



MAX

	Time [s]	Minimum [Pa]	Maximum [Pa]	Average [Pa]
1	0,	0,	0,	0,
2	1,4998e-003	0,	3,6112e-006	5,3225e-008
3	2,9999e-003	0,	1,0387e+008	1,1938e+006
4	4,4999e-003	0,	1,4078e+008	4,3662e+006
5	5,9999e-003	0,	1,6766e+008	7,4422e+006
6	7,4999e-003	0,	1,9281e+008	9,7041e+006
7	8,9999e-003	0,	1,9066e+008	1,0934e+007
8	1,05e-002	0,	1,6829e+008	1,2469e+007
9	1,2e-002	0,	1,8361e+008	1,303e+007
10	1,35e-002	0,	1,6496e+008	1,3458e+007
11	1,5e-002	0,	1,8853e+008	1,3707e+007
12	1,65e-002	0,	1,8603e+008	1,4273e+007
13	1,8e-002	0,	2,0229e+008	1,4555e+007
14	1,95e-002	0,	1,8541e+008	1,5073e+007
15	2,1e-002	0,	1,7935e+008	1,5585e+007
16	2,25e-002	0,	2,3162e+008	1,5805e+007
17	2,4e-002	0,	2,4866e+008	1,616e+007
18	2,55e-002	0,	2,2683e+008	1,6525e+007
19	2,7e-002	0,	2,3981e+008	1,6376e+007
20	2,85e-002	0,	2,2775e+008	1,6528e+007
21	3,e-002	0,	2,4517e+008	1,6458e+007
22	3,e-002	0,	2,4517e+008	1,6458e+007

Conclusions

- There is a need for advanced tools to explore **shape variants** in the crashworthiness field
- **Mesh morphing** sounds as a good tool to reuse existing and validated FEA models
- In this study we presented a new approach based on LS-DYNA, Ansys Mechanical and RBF Morph that allows to predict the crash of a reshaped car bonnet **without** the need of a new **FEA mesh**
- Easy design and **shape optimization** coupled with LS-DYNA explicit solver
- Working with AUTODYN and LS-DYNA@LS-DYNA solver settings
- Faster morphing only in **one Component Model**
- Intuitive and **same UI** of RBF Morph in Mechanical
- The proposed method was able to adapt the bonnet of a sedan onto the one of a pick-up

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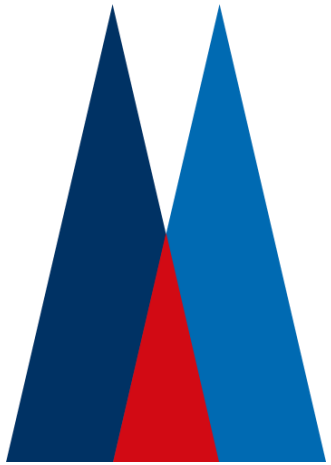

Thank you!

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