CADFEM CONFERENCE 2024
EMPOWERING DIGITAL ENGINEERING

RBF Morph

Complete Solution for Delivering Interactive Digital Twins with Custom AR/VR UI

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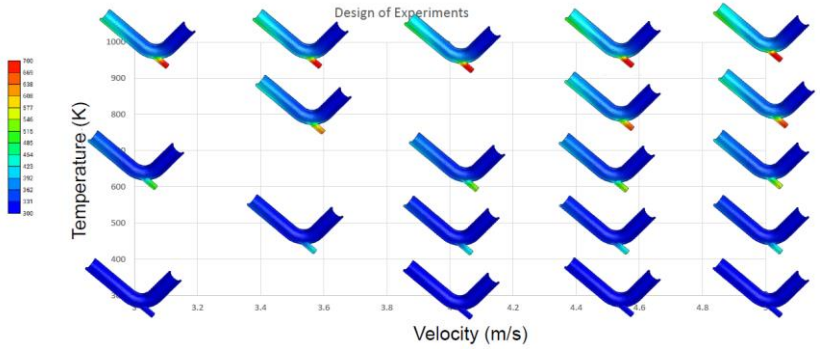
rbf™

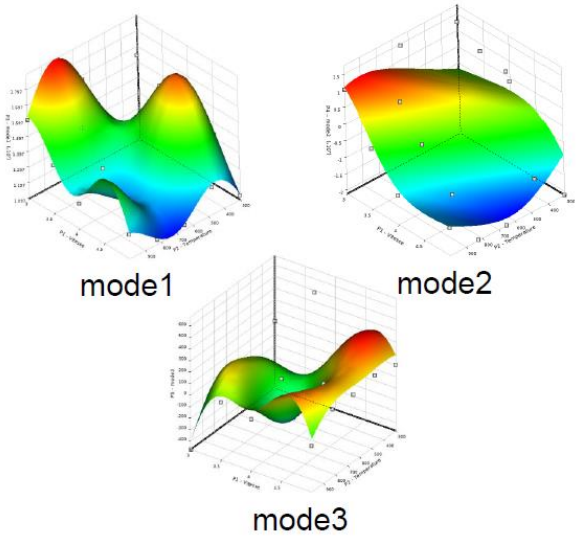
TOR VERGATA
UNIVERSITÀ DEGLI STUDI DI ROMA

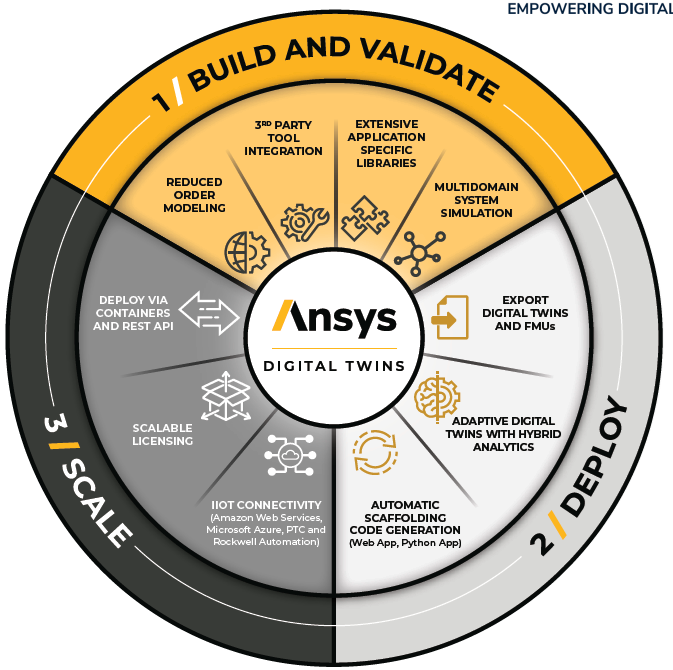
Interactive Digital Twins?

- High-fidelity simulations big data for training AI models:
  - Design stage: steer new projects more effectively
  - Operation stage: **real-time** interactions are key enablers of digital twins
- Challenges:
  - High level of automation required
  - Replicable, easily deployable workflow
- We present a comprehensive solution based on Ansys CAE tools powered by **Unity rendering** and exported to **Meta Quest 3** AR/VR

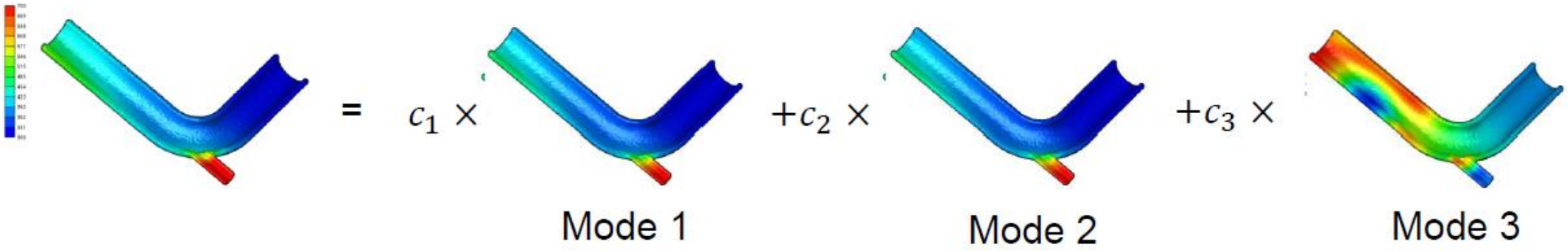
Reduced order models



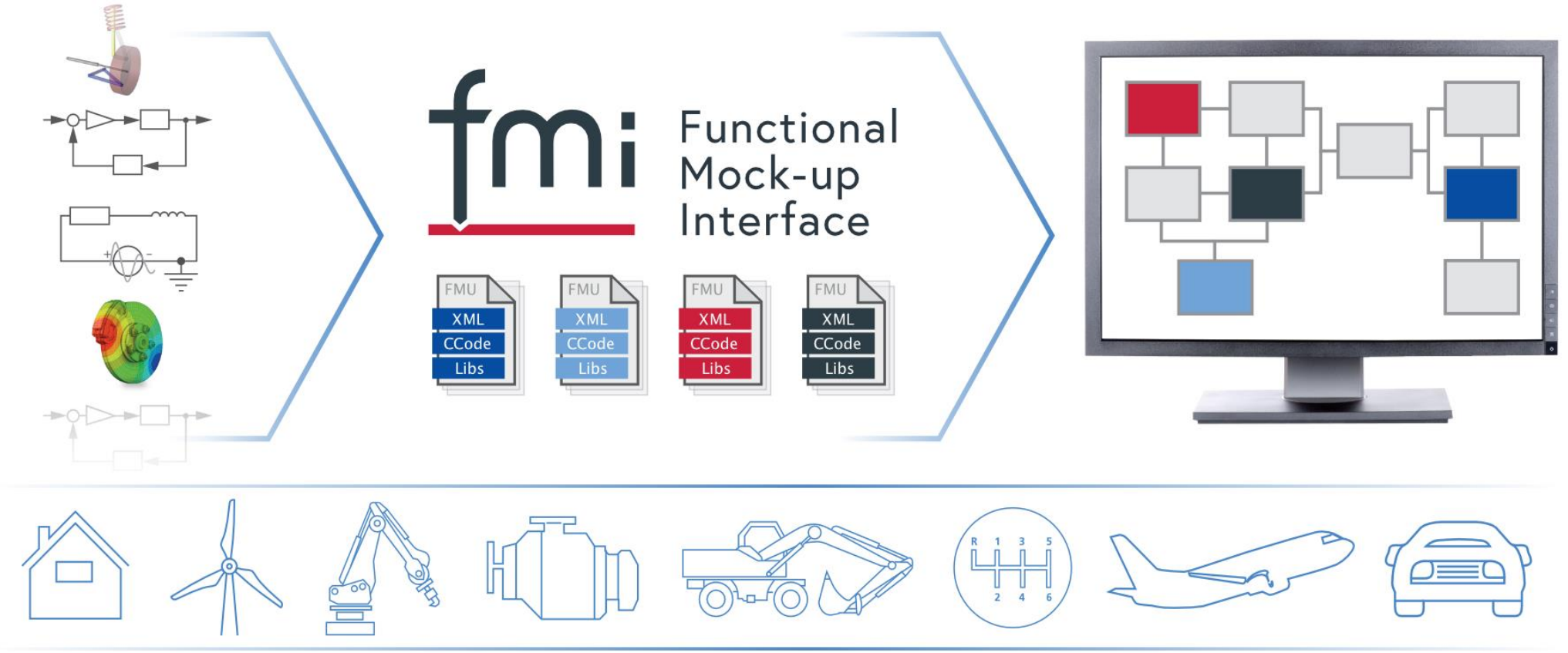




POD+GARS = ROM

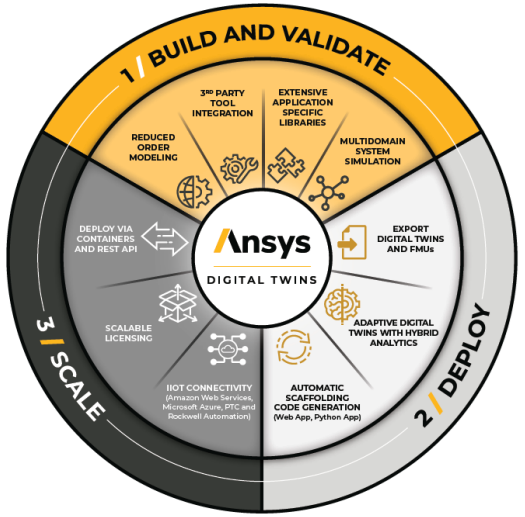


Functional mock-up units



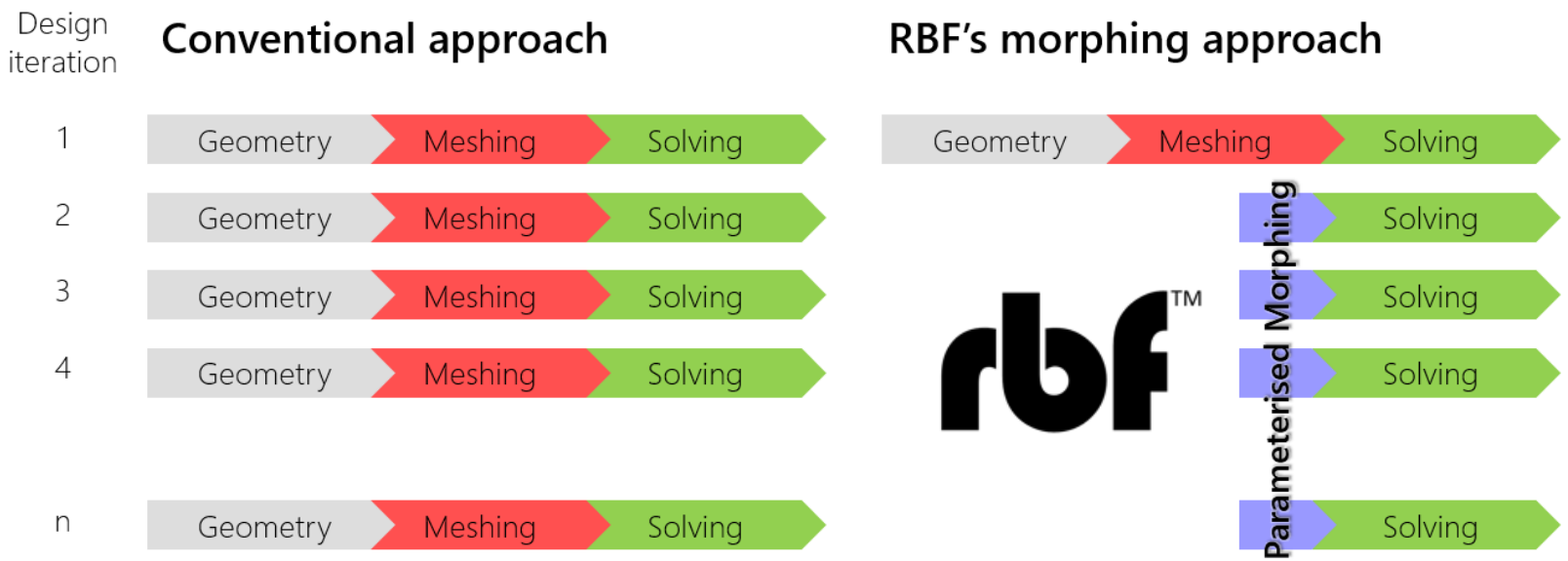
Interactive Digital Twins Challenge #1

- High level of automation to create snapshots is needed
- Geometrical parameters require mesh topology preservation



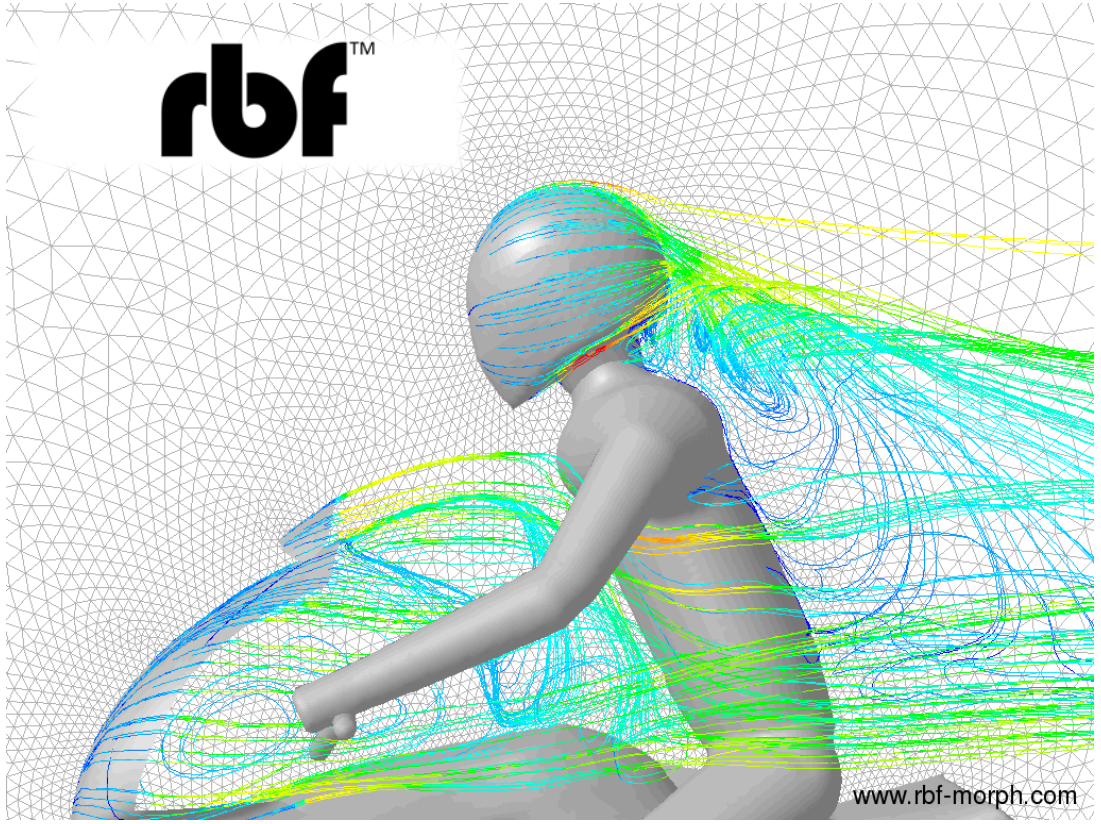
We make CAE models parametric

- RBF Morph makes the CAE model **parametric**
- Shape parameters are driven by **an orchestrator**
- Shape parameters can be used to generate snapshots for real time Digital Twins (**ROM/AI**)



Radial Basis Functions mesh Morphing

- Geometric control by **R**adial **B**asis **F**unctions mesh **Morph**ing
  - Surface shape changes
  - Volume mesh adaption
- A **new shape** of the CAE model **ready to run**
  - for structures in the FEA solver
  - for flows in the CFD solver



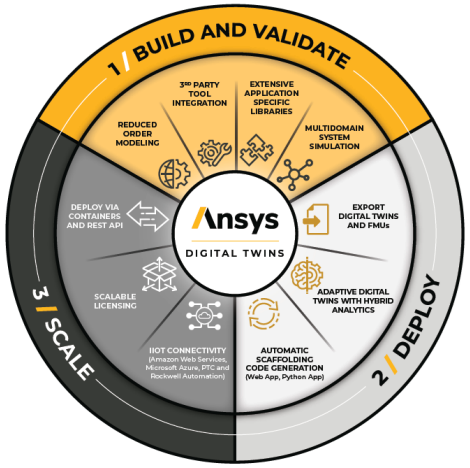
Radial Basis Functions mesh Morphing

- We offer **Radial Basis Functions** (RBF) to drive mesh morphing (smoothing) from a list of source points and their displacements

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

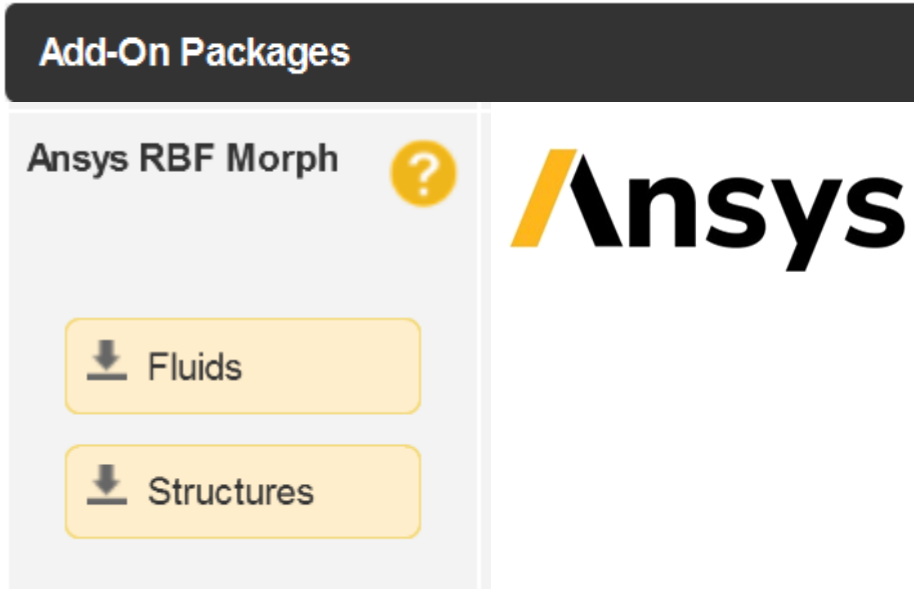
- RBF are recognized to be one of the **best mathematical tools** for mesh morphing

Ansys RBF Morph products



Ansys OPTISLANG

- An RBF mesh morphing solution fully embedded in Ansys
  - **RBF Morph Fluids** – an Add On for Fluent
  - **RBF Morph Structures** – an ACT App for Mechanical
- Full integration with **optiSLang** and **Twin Builder**
- Support for **LS-DYNA** and **APDL**



https://www.rbf-morph.com/wp-content/uploads/2023/05/RBFMorph_Brochure.pdf

Ansys SELECT TECHNOLOGY PARTNER

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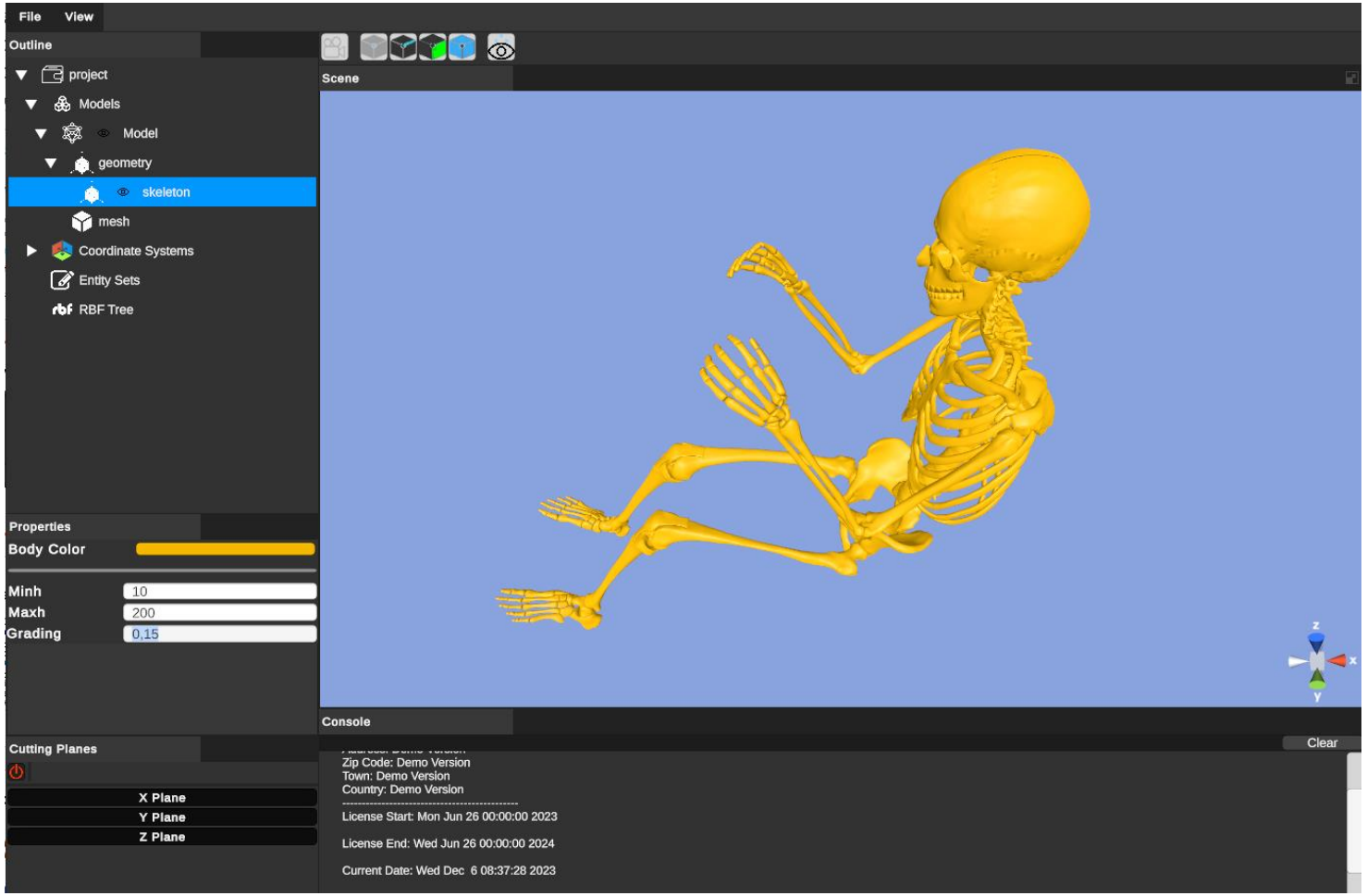
New RBF Morph Stand Alone

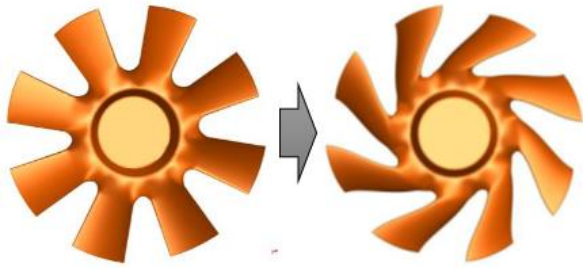
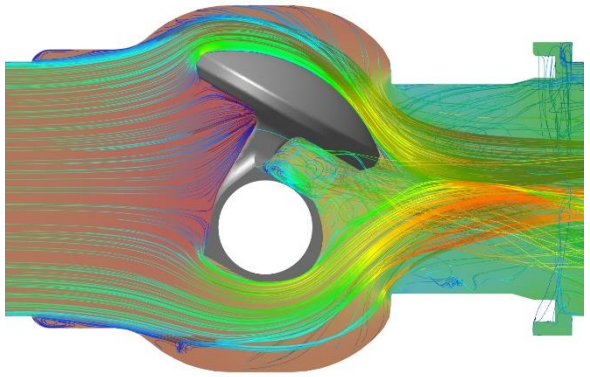
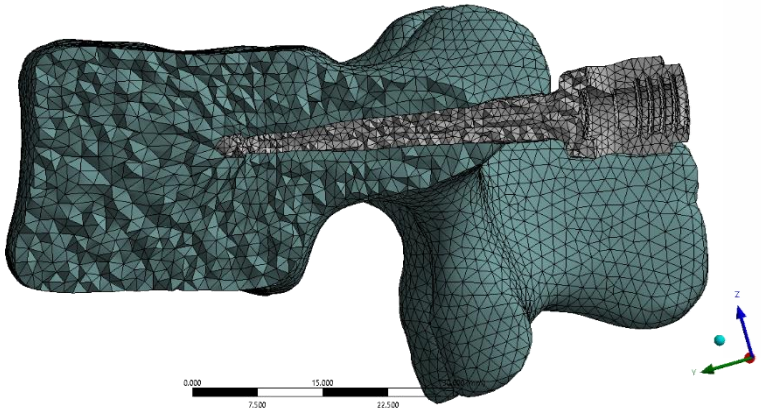
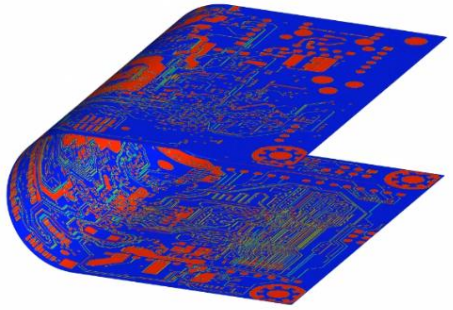


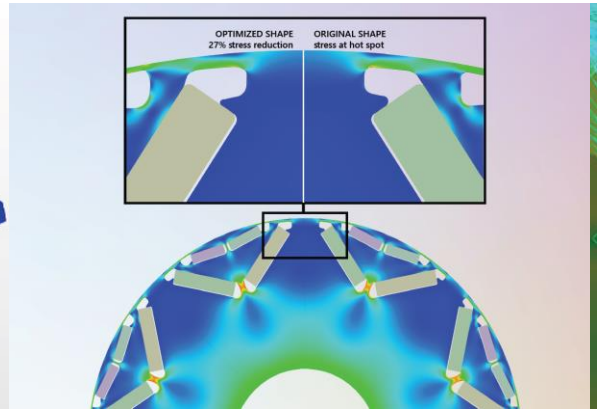
- To be released in 2024
- Read in **STL, STEP**
- **Unity - OpenCascade**
- Solver independent process that supports **many mesh formats**
- **Scriptable** via Python

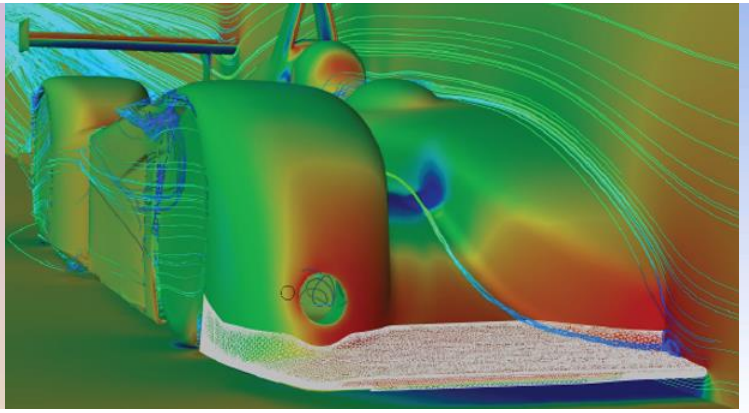
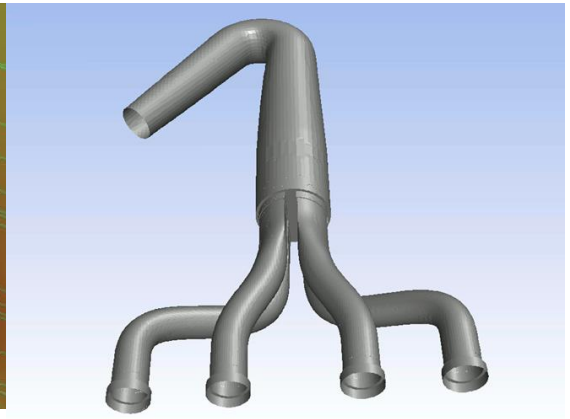
Main uses of RBF Morph

Usage	Mechanical	Fluent	optiSLang	Twin Builder
Automated and quick variable design space exploration.	✓	✓		
Optimization (Single physics or multi-physics). Shape optimization for stress reduction, mass reduction, fluid-structure interaction	✓	✓	✓	
Digital twin development (static ROMs)	✓	✓	✓	✓
Lifing applications Simulate defects such as corrosion pits, spalling of material, erosion, chips, etc.	✓	✓		
Examine the effects of non-conformance and manufacturing variability	✓	✓		
Robust Design	✓	✓	✓	

Applications



EU-funded research projects

RBF4AERO

FORTISSIMO

RIBES

Cloudi Facturing

EUROfusion

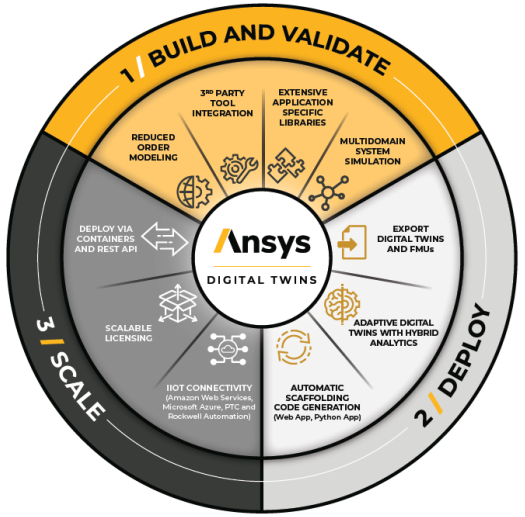
spinner
next generation spine experts

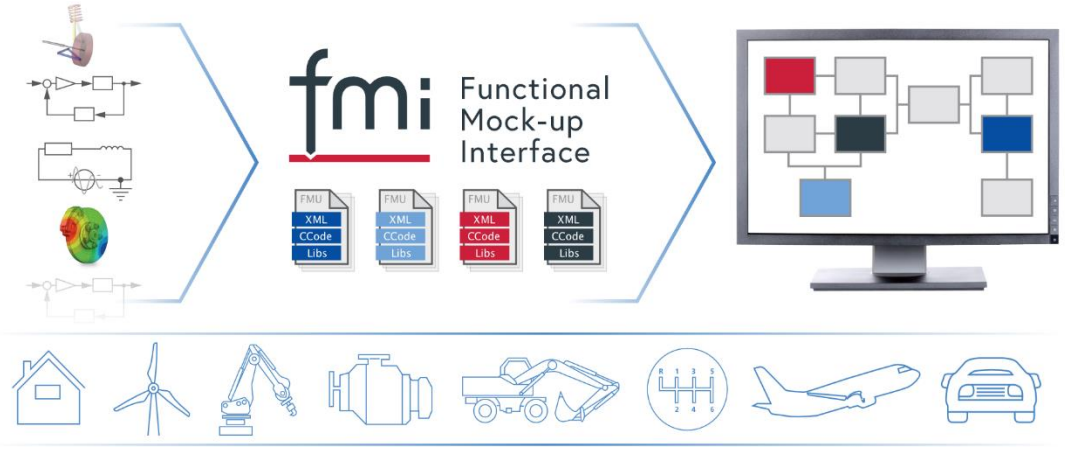
MEDITATE

f4f EuroHPC

Interactive Digital Twins Challenge #2

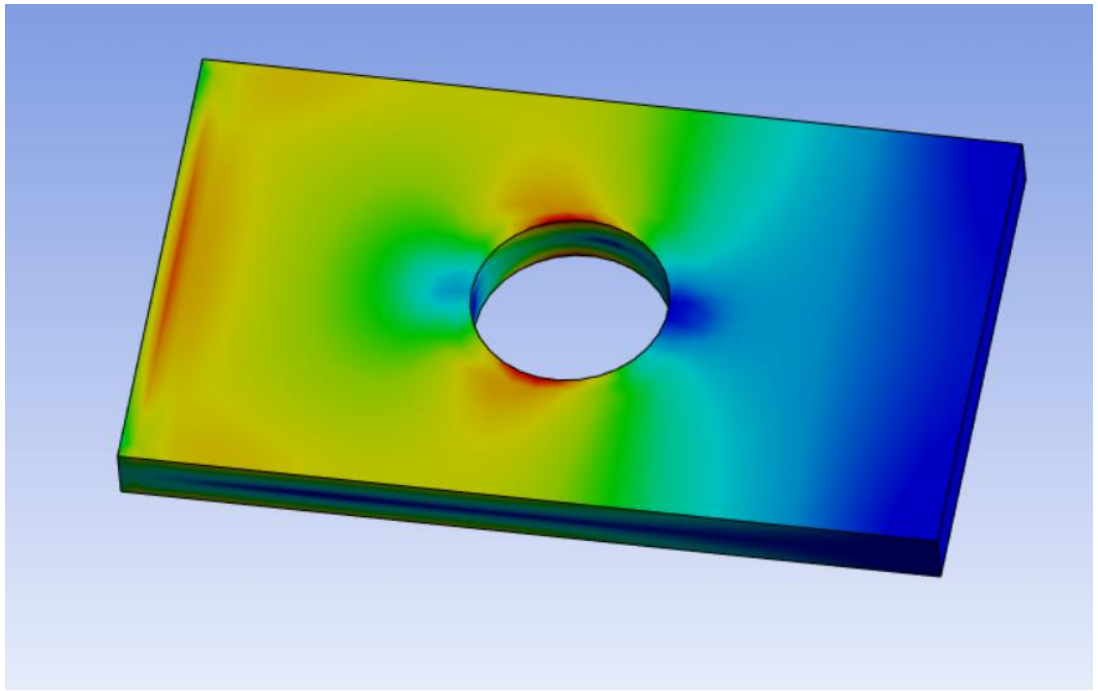
- Replicable, easily deployable workflow?
- Unity rendering
- Meta Quest 3 AR/VR
- Apple VisionPro?



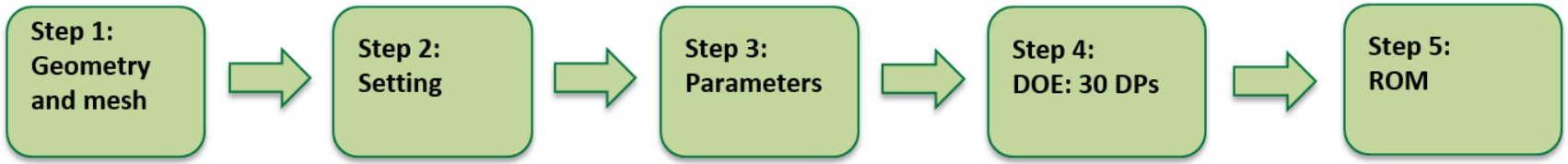


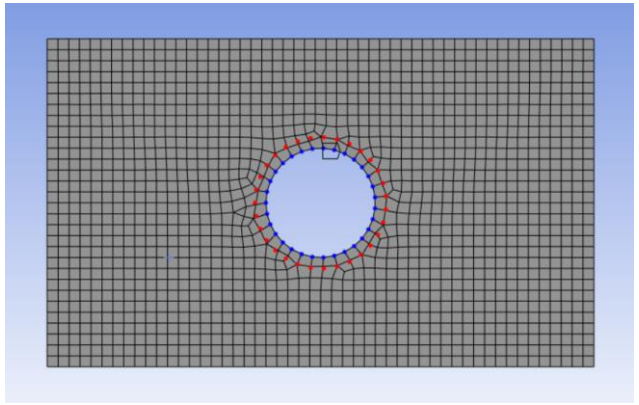
A simple FEA model – ROM - FMU

- Solid model created by CAD
- The notch effect is accurately captured by Mechanical
- RBF Morph allows to create **one geometrical parameter** to change the diameter of the hole
- The applied loads is the **physical parameter**
- Snapshots are exported and the FMU created by Twin Builder

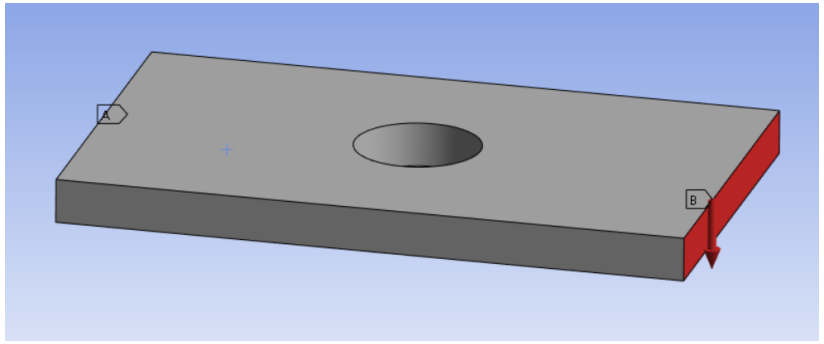


Workflow

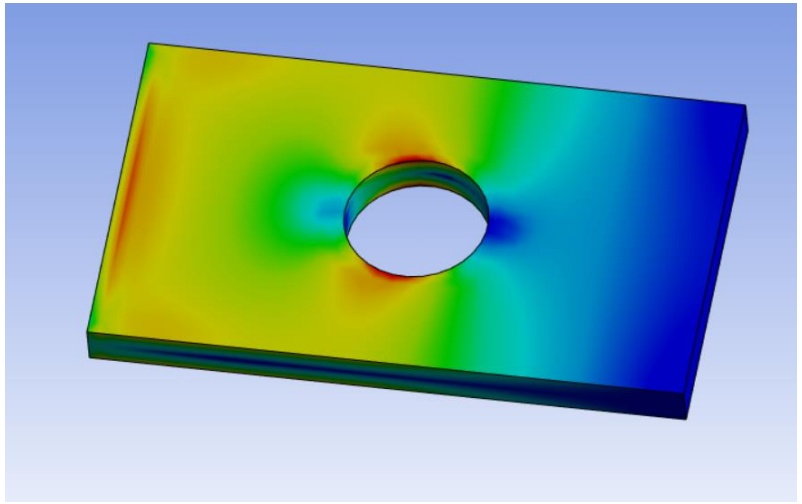




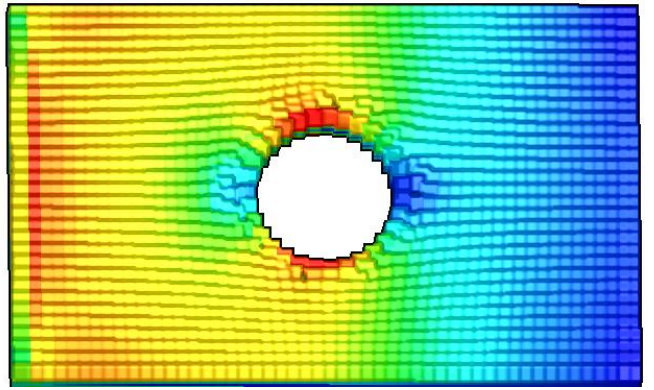
Shape parameter: radius offset

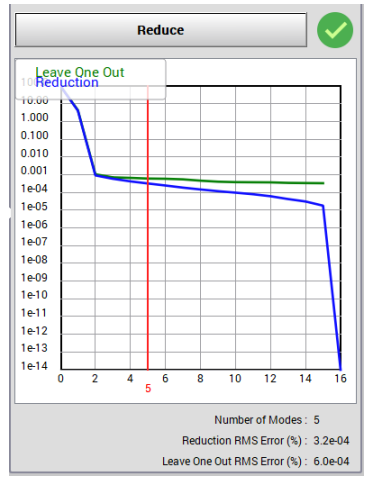


Physical parameter: Force



VM stresses





Ansys TB interface

Ansys SELECT TECHNOLOGY PARTNER

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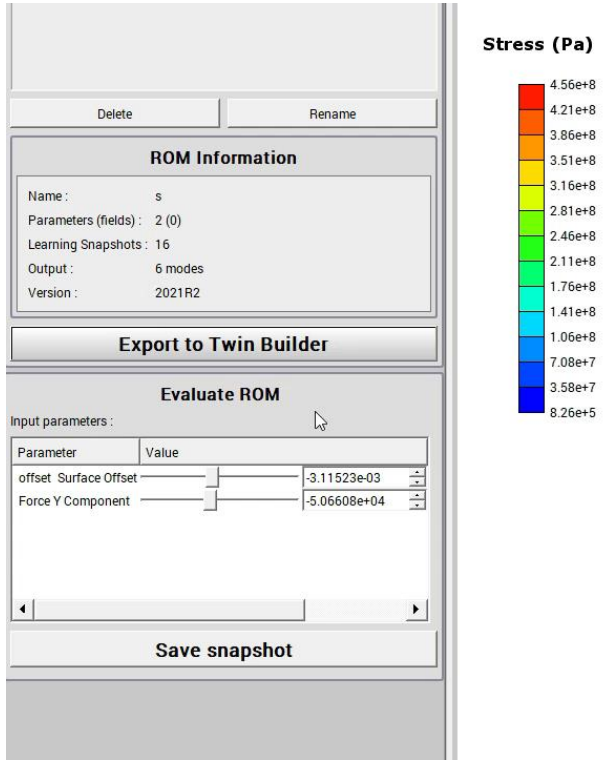
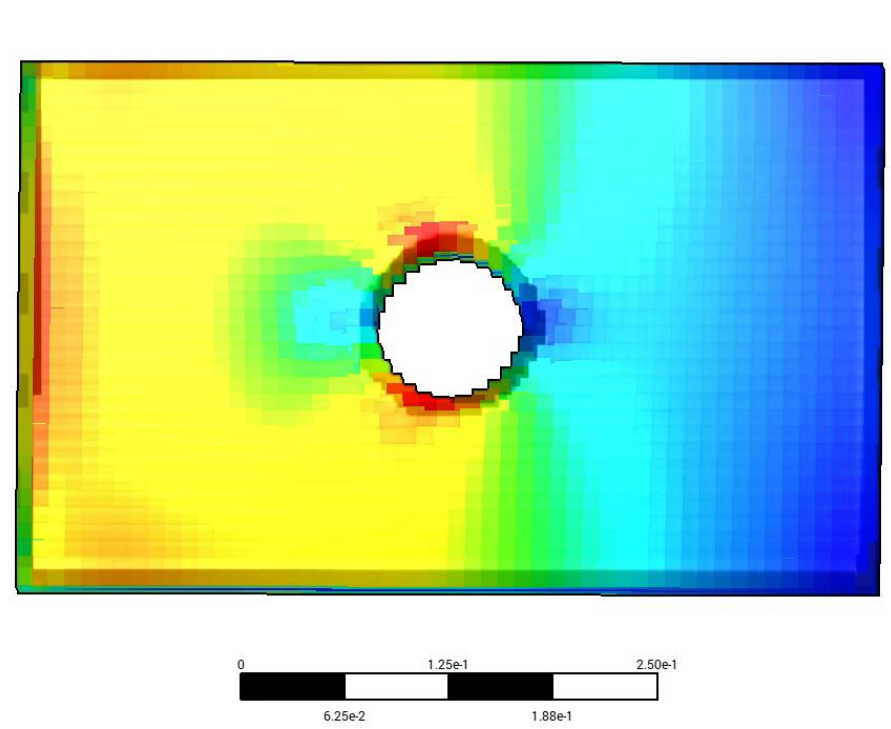
Twin Builder

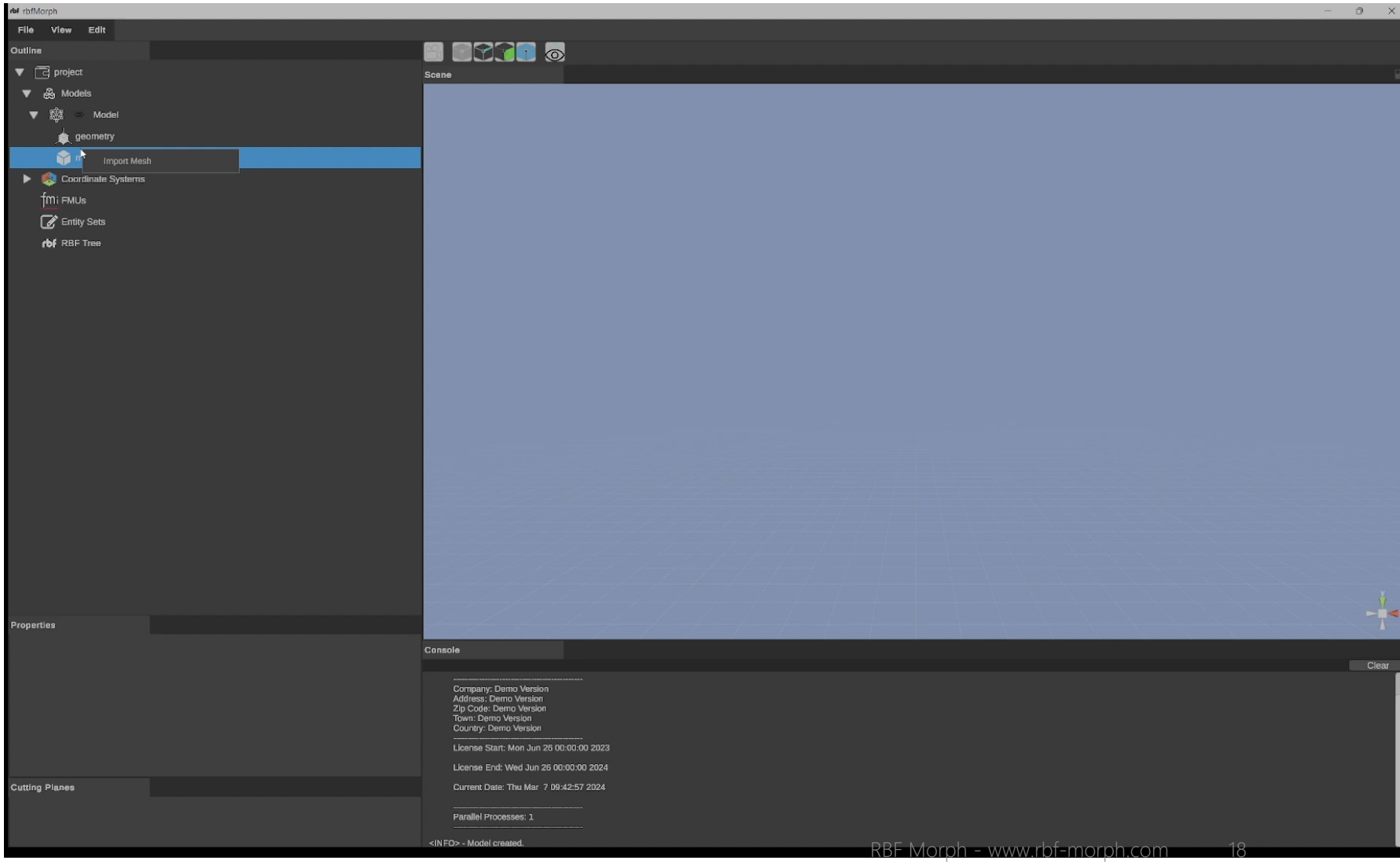
- ROM viewer
- Input parameters are controlled by the sliders
- **Point-based** rendering





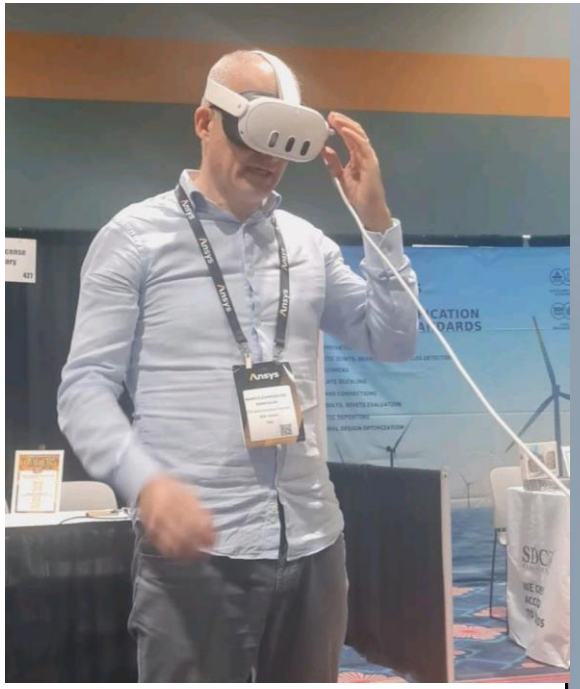
RBF Morph Unity UI

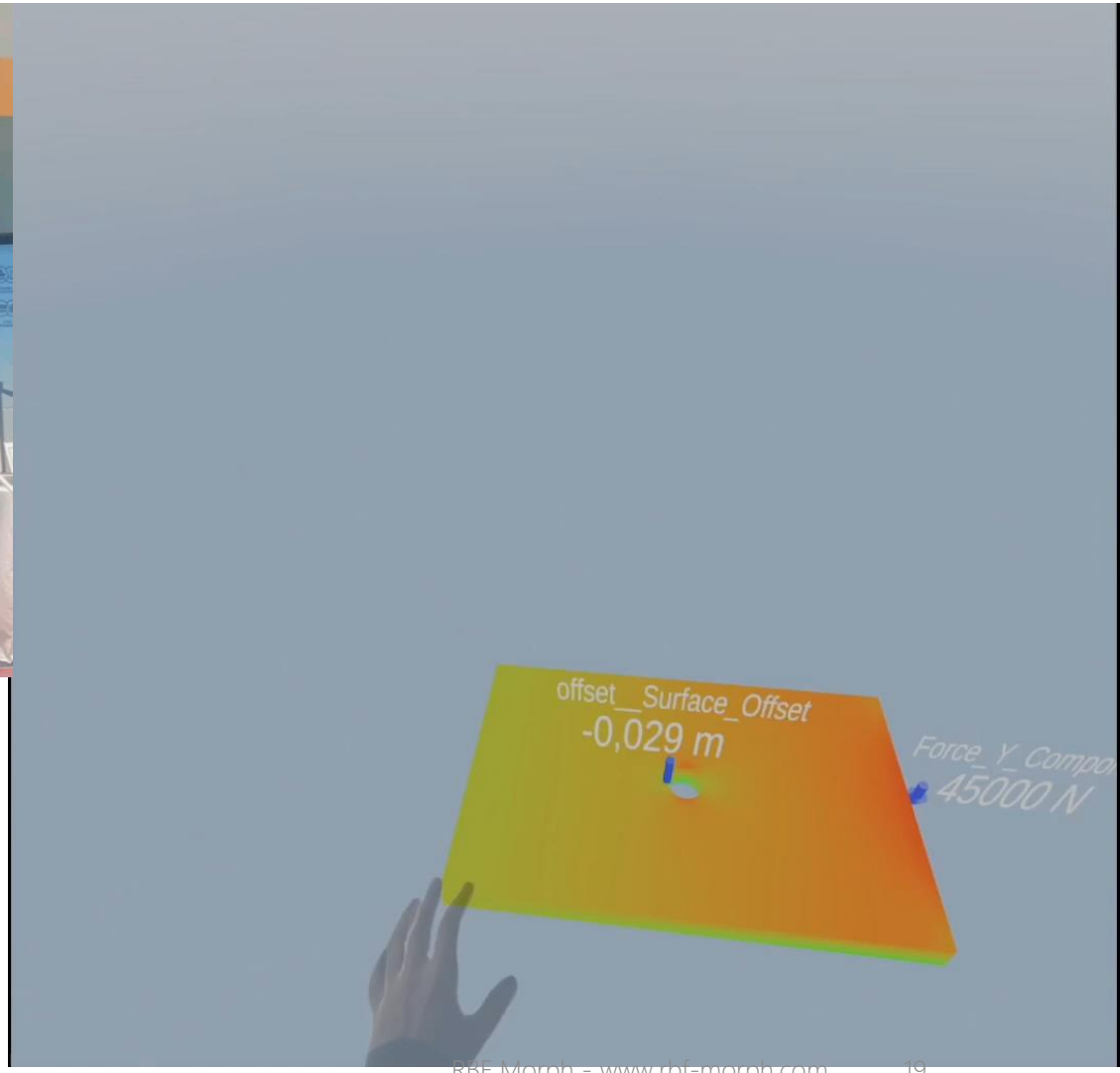
- Unity UI capable to read in stl and FMU
- Input parameters are controlled by **handles** (json descriptor)
- **Surface-based** rendering



RBF Morph exported VR

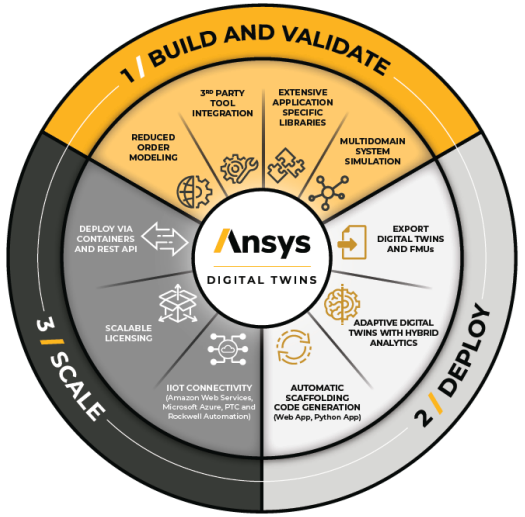
- FMU are translated to ARM
- Meta Quest 3
- Input parameters are controlled by hands
- We can add an **immersive scene**
- Wireless AR/VR

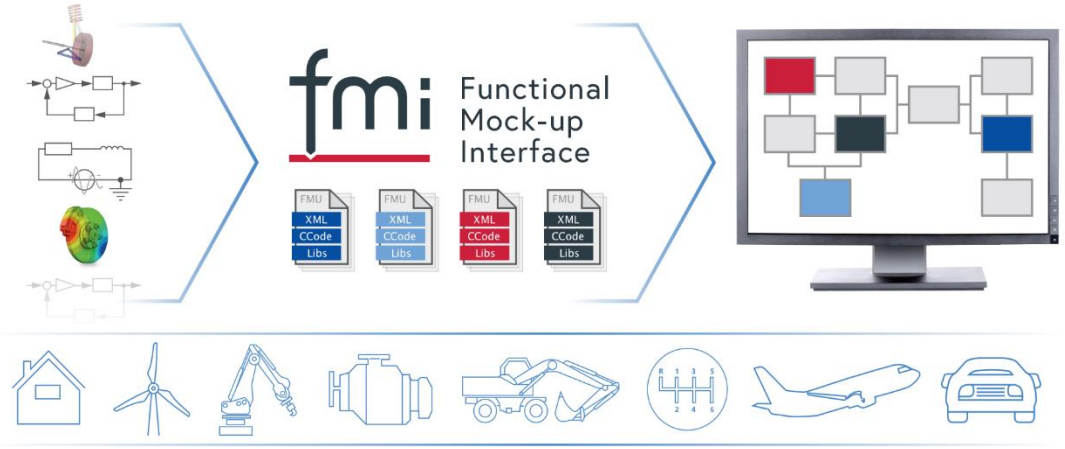




Interactive Digital Twins? Yes!

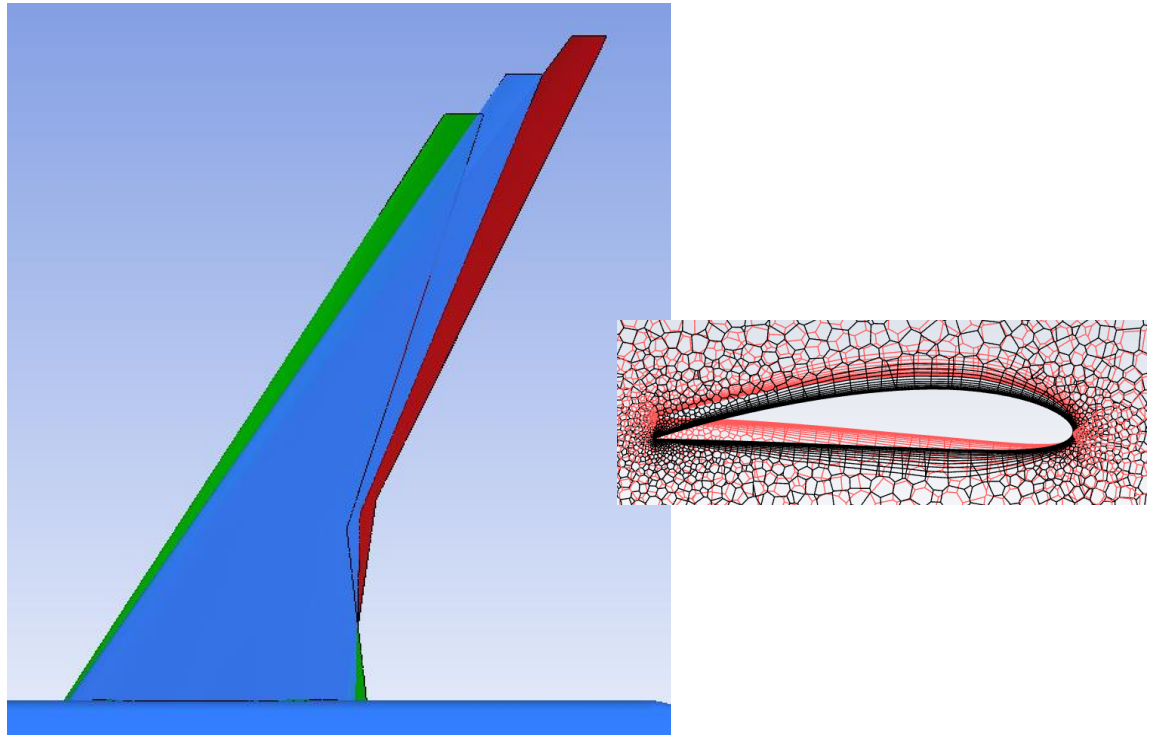
- Examples
  - **Aeronautical** – interactive aircraft aero design in the RBF Hangar (Fluent)
  - **Space** – structural optimization of the CUSP CubeSat in the virtual lab (Mechanical)
  - **Automotive** – aero optimization of a sedan car in the RBF Autosalon (Fluent)
  - **Healthcare** – aneurysm repair (LS-DYNA)





Open Parametric Aircraft Model (OPAM) testcase

- Parametric CAD model of the OPAM, an aircraft model inspired by the Boeing 787-800 Dreamliner
- 6 shape parameters are considered 66 snapshots generated
- CFD solver: **Ansys Fluent**



	Aspect r	Sweep	Alpha b	Camber b	Alpha t	Camber t
Range	8 ÷ 10	33 ÷ 37	-5 ÷ -1	0.02 ÷ 0.06	-10 ÷ -6	0.02 ÷ 0.06
Baseline	9	35	-3	0.04	-8	0.04

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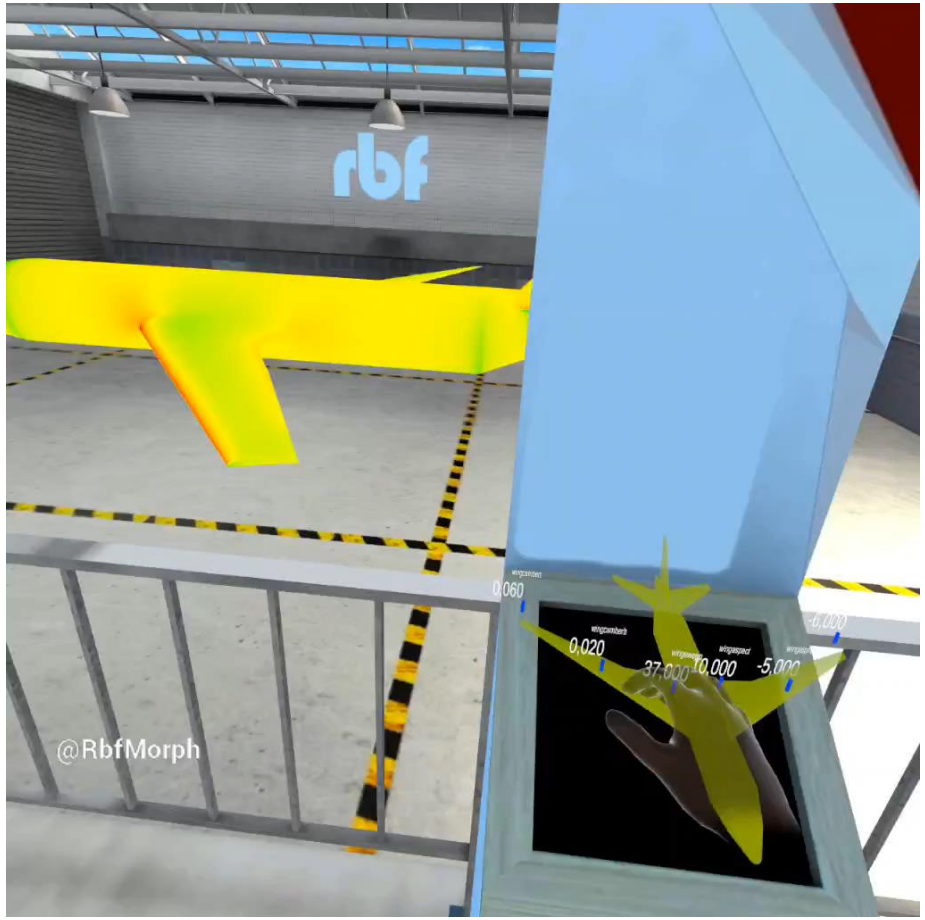
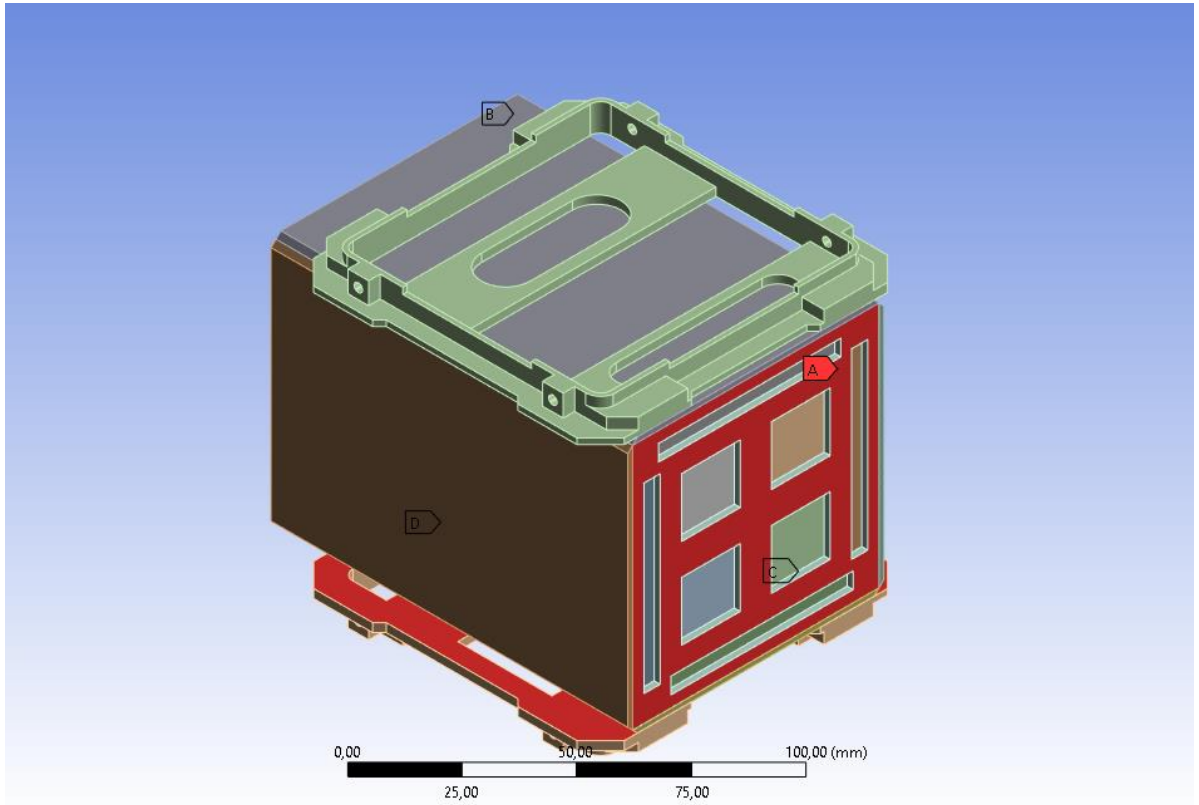


Case study: Cubesat Thermo-Mechanical Optimization

- The **Cubesat** shown in figure is subject to two different **thermo-mechanical** load conditions
- Eyelets and thickness optimization through mesh morphing
- FEA solver: **Ansys Mechanical**



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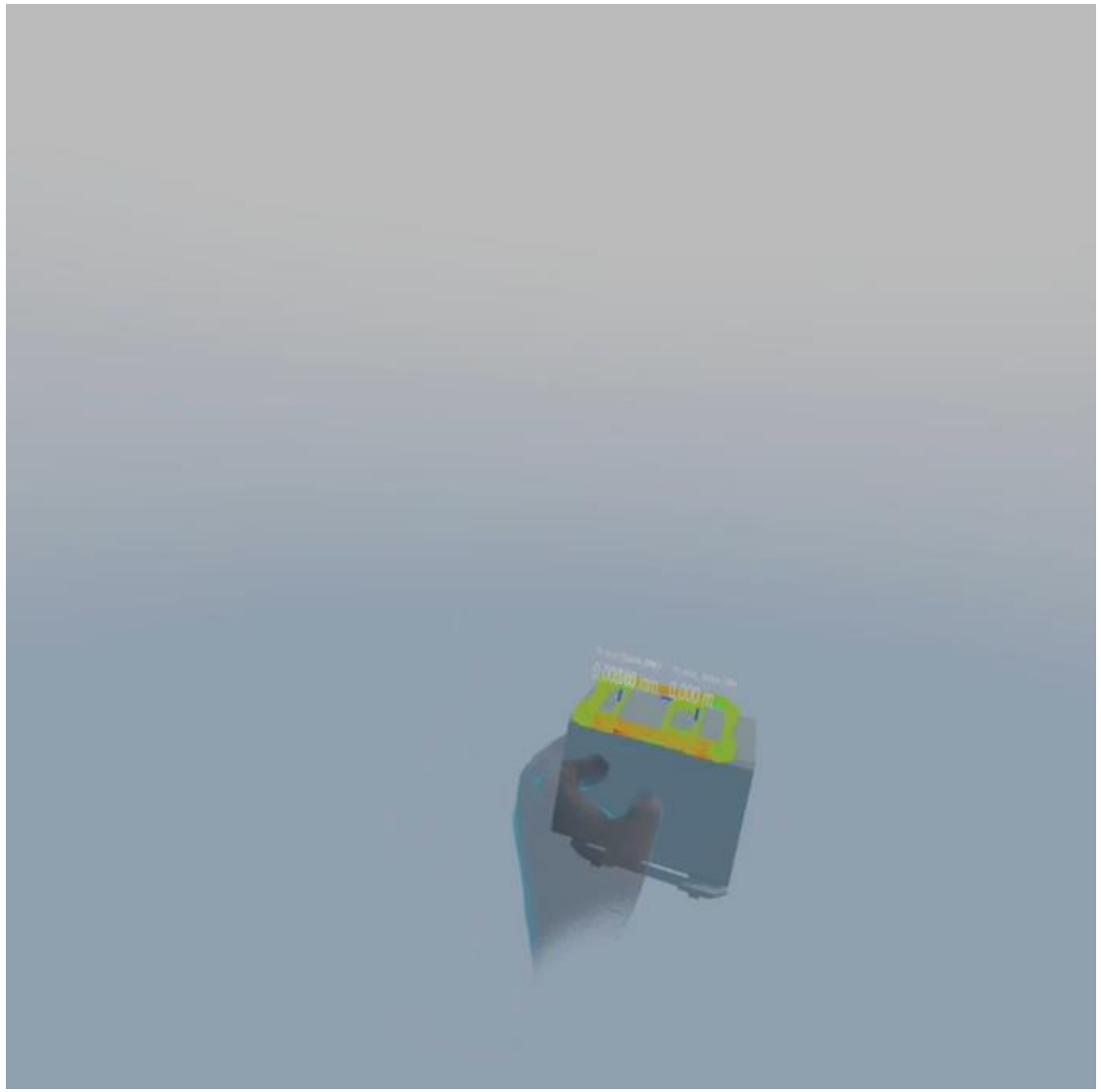
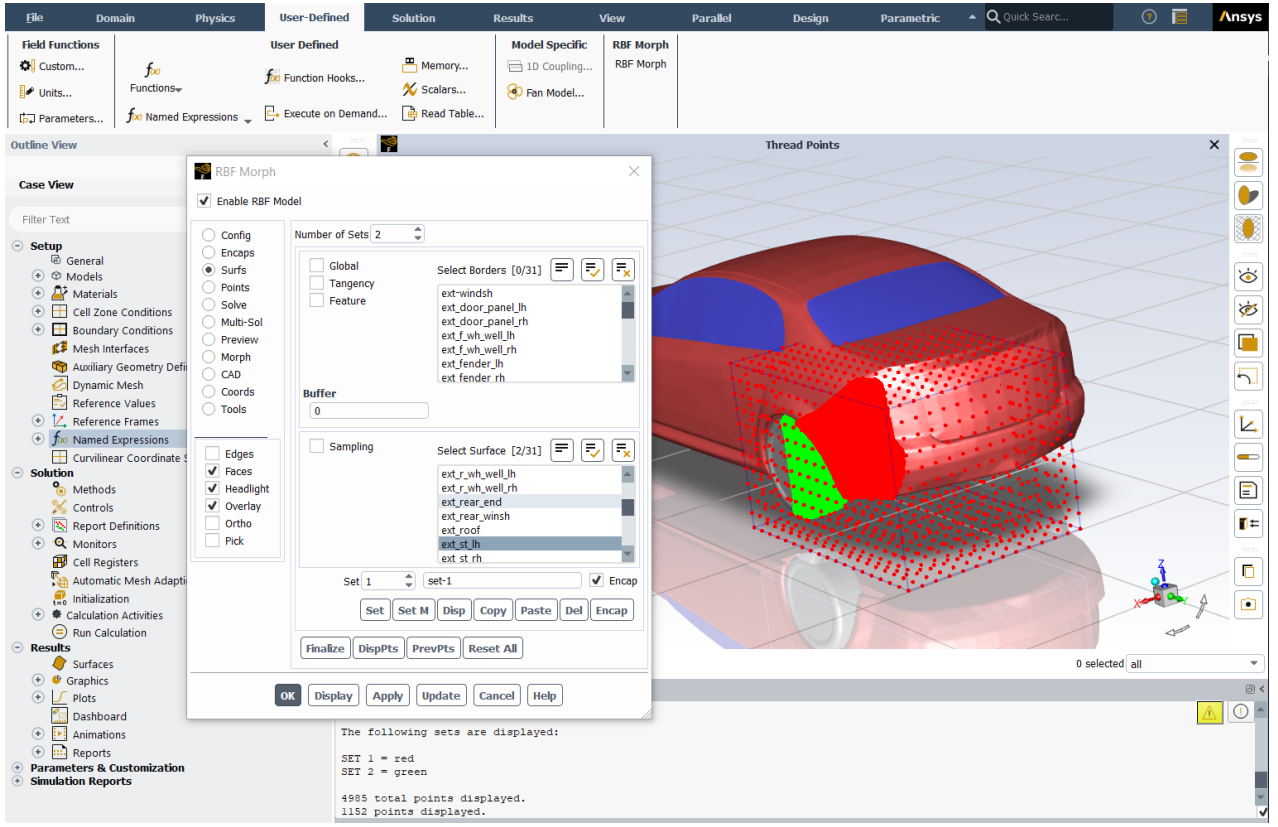


Sedan Car Aero optimization

- Two shape parameters are defined in the RBF Morph Fluids UI
- Design variations explored real time
- CFD solver: **Ansys Fluent**



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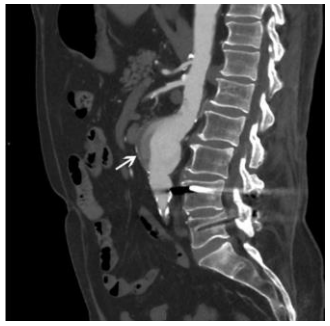
MeDiTATe Endovascular Abdominal Aneurysm Repair

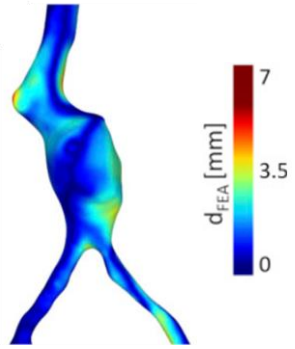
AAA patient case

ST. OLAVS HOSPITAL
UNIVERSITETSSYKEHUSET I TRONDHEIM



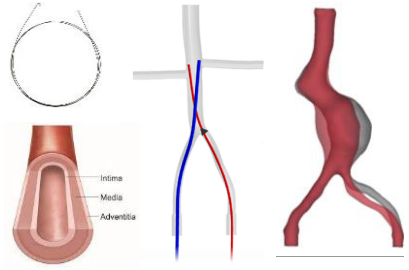
CT scan segmentation

3DSlicer



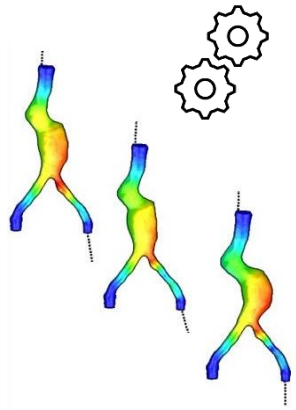
Baseline Finite Element case

Ansys LS - DYNA



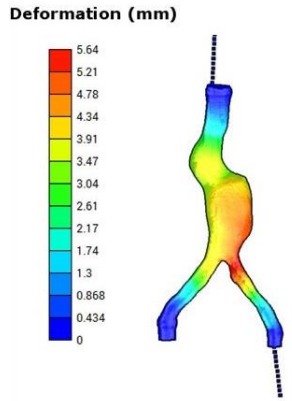
Morphological, clinical, mechanical parameterization

rbf™ python™



ROM Build-up

Ansys TWIN BUILDER



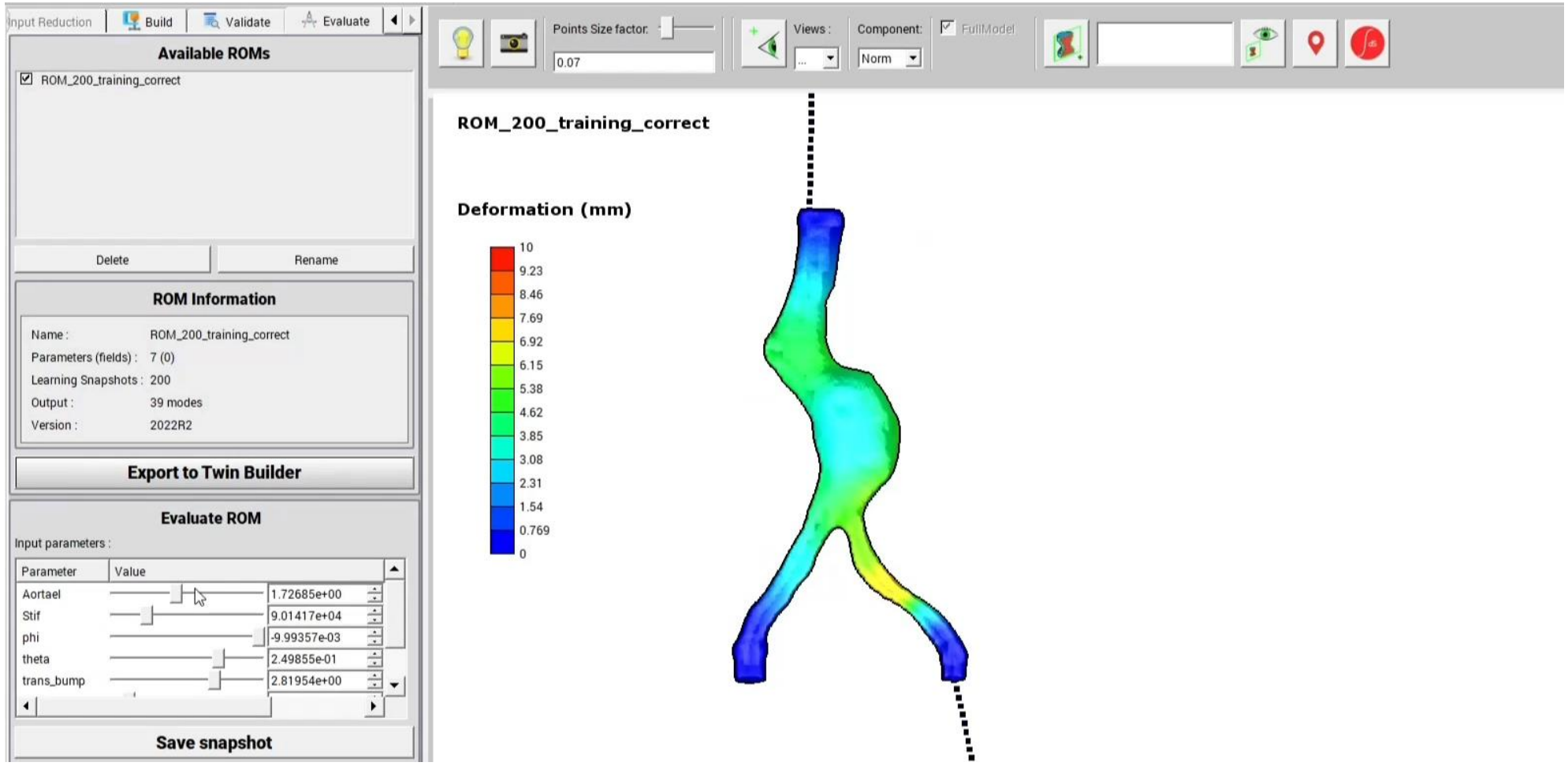
ROM exploitation

Ansys TWIN BUILDER

Ansys SELECT TECHNOLOGY PARTNER

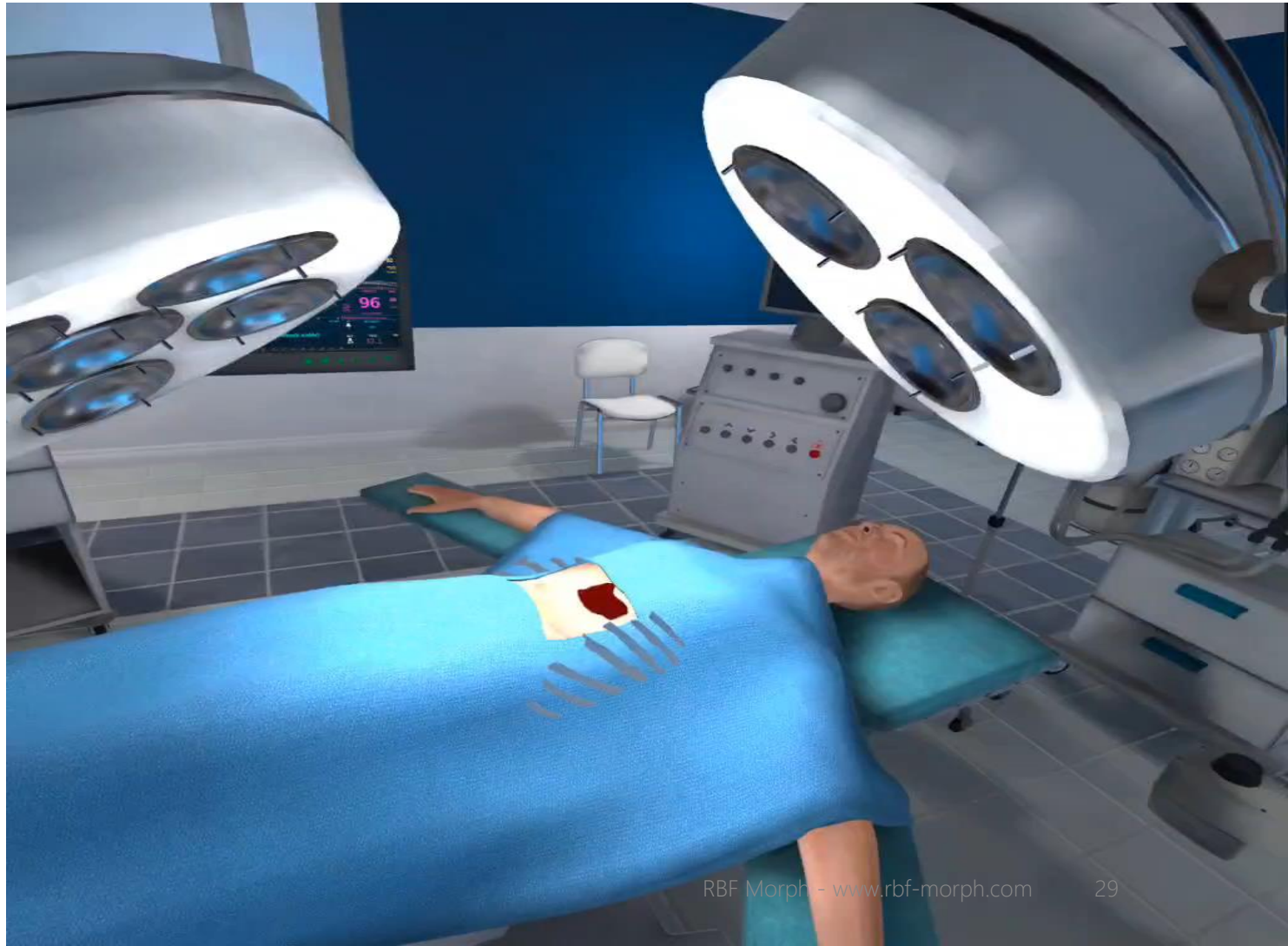
rbf™

MeDiTATe Endovascular Abdominal Aneurysm Repair



MeDiTATe Endovascular Abdominal Aneurysm Repair

- FMU are translated to ARM
- Meta Quest 3
- Input parameters are controlled by hands
- FEA solver: **LS-DYNA**



Conclusions and next steps

- Interactive **Digital Twins? Yes!**
- We have a **complete workflow** based on Ansys products:
  - High fidelity solvers (Mechanical, APDL, LS-DYNA, Fluent)
  - Twin Builder
  - RBF Morph
- The approach is generic, **surface-based**, we work with FMU and stl files
- We support ARM (Android), we are now considering **Apple VisionPro**
- Wireless AR/VR
- We are extending our implementation to **volume results** (internal stress, streamlines)

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EMPOWERING DIGITAL ENGINEERING

Thank you!

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