FUSION FOR ENERGY

Technology Development Programme

Metrology & Reverse Engineering Workshop

Session:

Core Metrology & Reverse Engineering Practices

Topic:

Advanced Reconstruction: Creating the As-Built Model

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Quick Introduction

Professor of Machine Design

University of Rome Tor Vergata

High fidelity CAE optimization.
Geometric Intelligence with Radial Basis Functions.

www.rbflab.eu

Company Founder

RBF Morph srl

Advanced mesh morphing technology for CAE.

www.rbf-morph.com

www.rbfcae.com

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What do we mean?

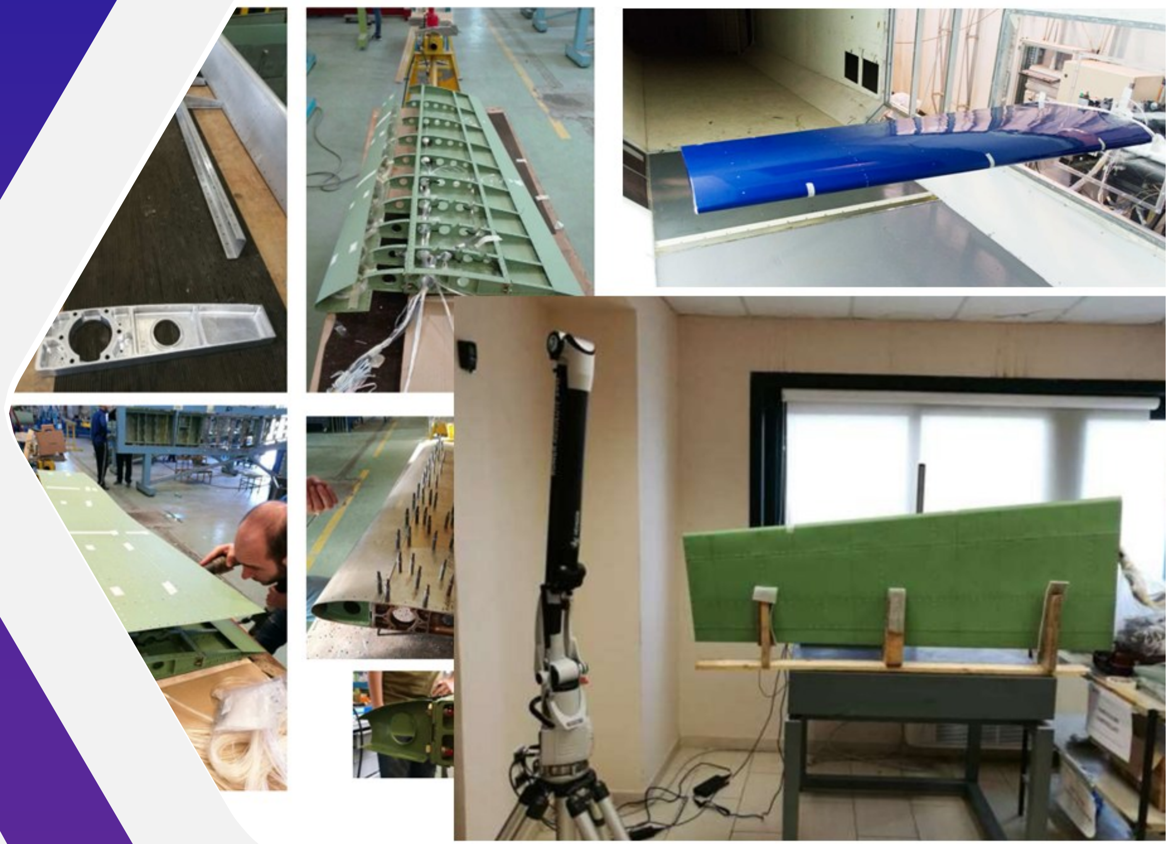
We call "As-Built" the actual shape as resulting from the manufacturing processes. Its digital representation helps us especially in non-conformal cases to understand and eventually approve the usage.

The As-Built shape is the result of a post-processing of surveyed data (cloud of points, acquired profiles). A CAD representation of this geometry is very useful for subsequent actions. A CAE representation help us in the qualification.

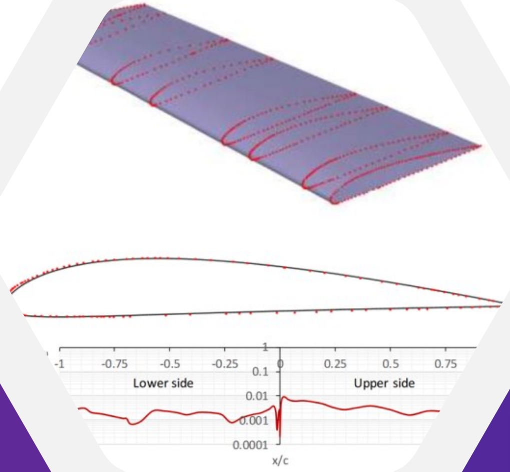
Advanced Reconstruction Creating the As-Built Model

Clean Sky

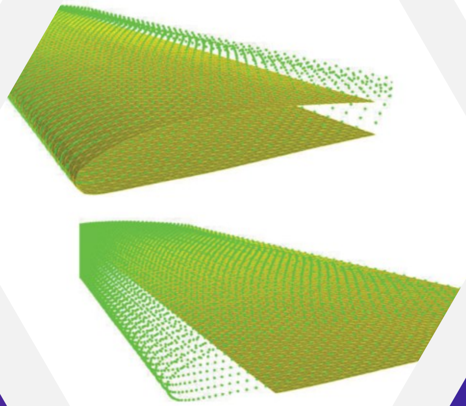
R I B E S



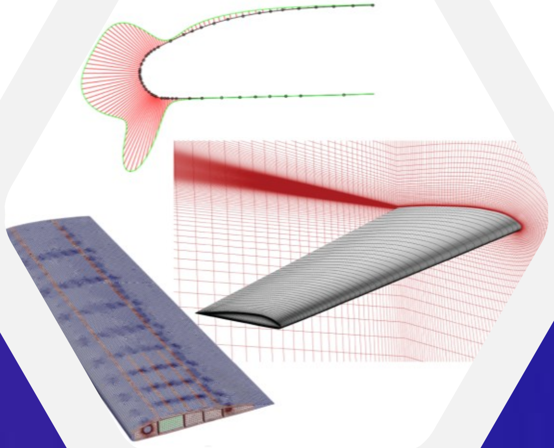
Advanced Reconstruction
Creating the As-Built Model



Surveyed cloud and nominal CAD pre-processing (scaling, alignment, filtering)



Space warping tools for mesh morphing (radial basis functions)



Update of CAE models (3d mesh), CAD models (iso-brep), surface models (STL)

Biancolini, M., E. and Cella, U. (January 7, 2019). "Radial Basis Functions Update of Digital Models on Actual Manufactured Shapes." ASME. *J. Comput. Nonlinear Dynam*. February 2019; 14(2): 021013. https://doi.org/10.1115/1.4041680

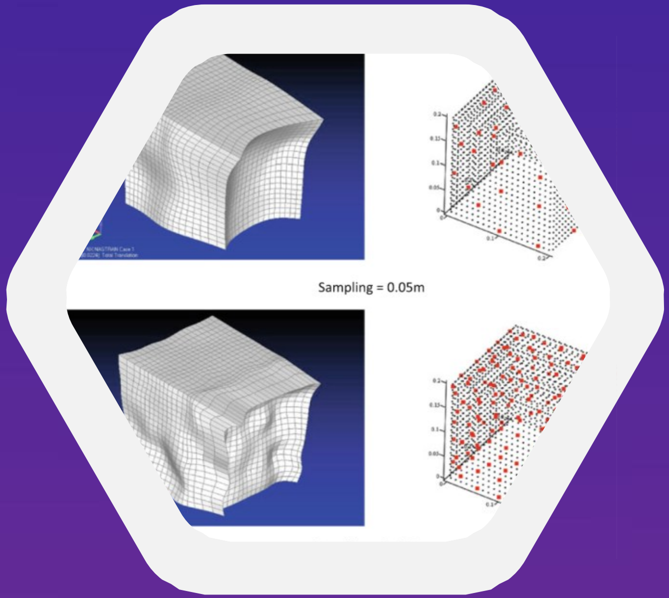
Surveyed cloud and nominal CAD pre-processing

Surveyed location are available as cloud of points. Alignment with the CAD (and adaption of units with scaling) is a standard and automated feature of all the metrology software.

Surveyed data contains noise. The noise can be related to the survey process itself. The noise could be due to a too fine resolution of the acquisition (up to the roughness scale). We filter up to the wave-length we want to represent.

Scaling & Alignment

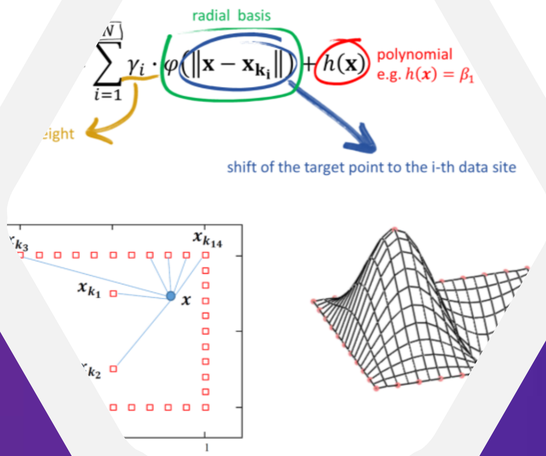
- Units consistency
- Orientation consistency
- Alignment (bounding box, least squares, Hausdorff distance)



Filtering

- De-noise by wavelength reduction with cloud decimation
- Least squares fitting of all the data on the decimated cloud

Space warping tools for mesh morphing: Radial Basis Functions



$$\begin{cases} s_x(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^x \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) \\ s_y(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^y \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) \\ s_z(\boldsymbol{x}) = \sum_{i=1}^{N} \gamma_i^z \varphi(\|\boldsymbol{x} - \boldsymbol{x}_{s_i}\|) \end{cases}$$

Radial Basis Functions

- Originally introduced by Hardy to reconstruct irregular surfaces (terrain/surface fitting).
- Meshless warping field.

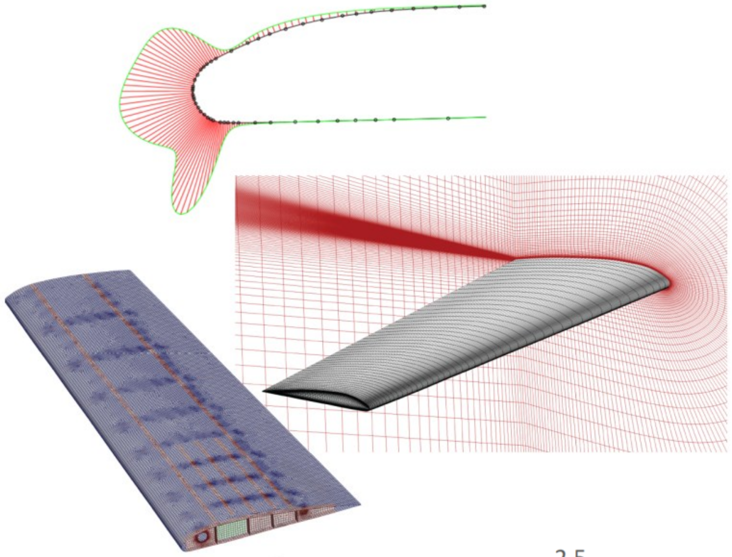
Fast Algorithms

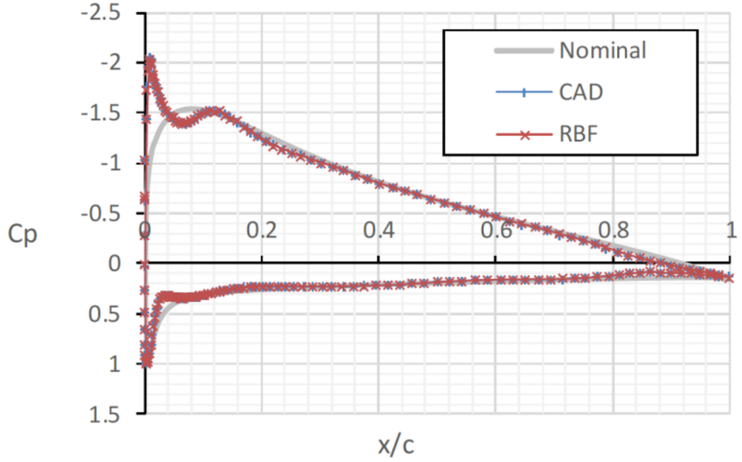
- Clouds are very large, up to millions and fast RBF are required!
- 700k points: 5 minutes on laptop,50 second on a WS.

Reusable warping fields

- Once trained the rbf can be reused for morphing (CAD, CAE)
- Fast evaluation (CPU and GPU)

Update of CAE models, CAD models, surfaces





The **update of CAE models, CAD models, surfaces** is needed for design refinement and maintenance .

- The updated CAE model (as built, as repaired, as eroded) acts as a Digital Shadow to understand the health status of the component
- The actual CAD representation helps the assembly
- Morphed surfaces are useful for interactive shape manipulation (including VR, XR)

What do we mean with

Advanced Reconstruction: Creating the As-Built Model

Relevancy of

Advanced Reconstruction: Creating the As-Built Model

Ideas of Development within

Advanced Reconstruction: Creating the As-Built Model

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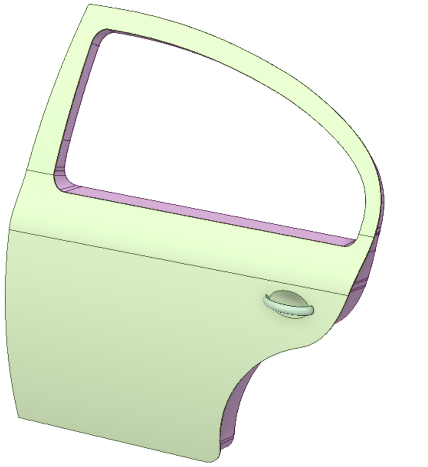
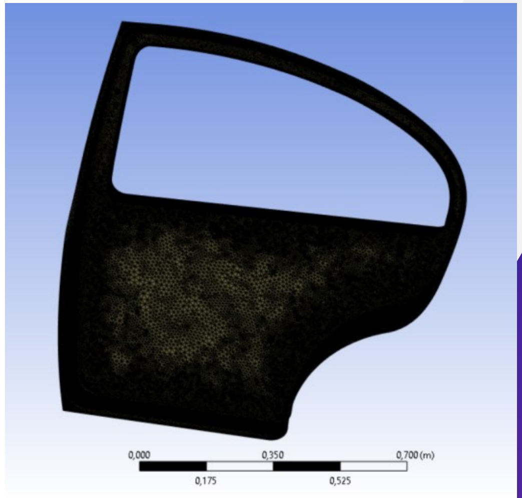
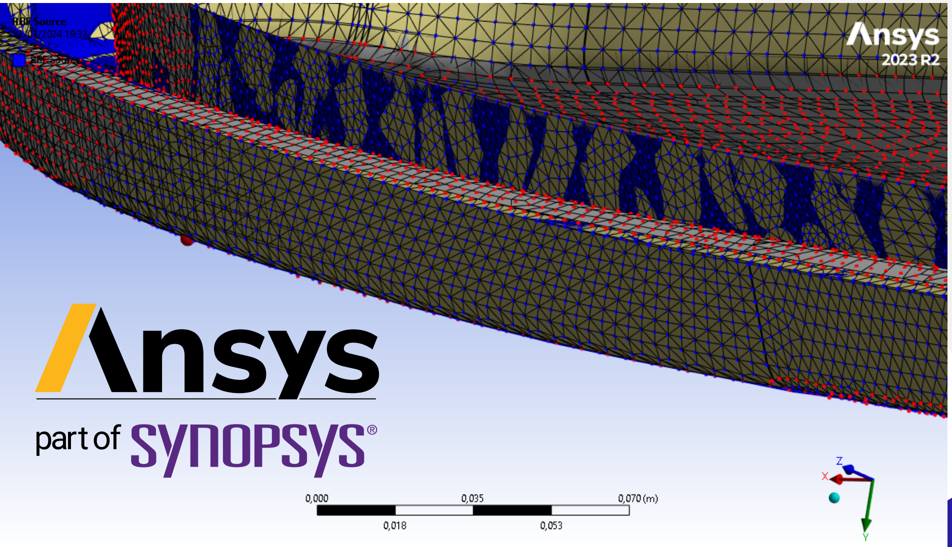
Case study 1: Car door



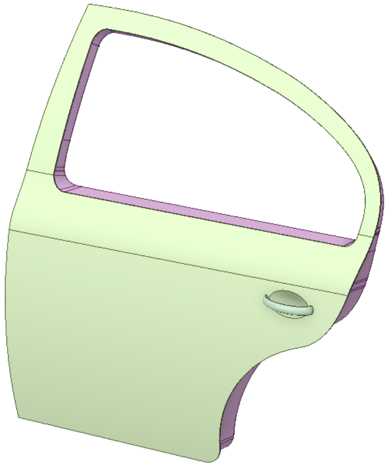


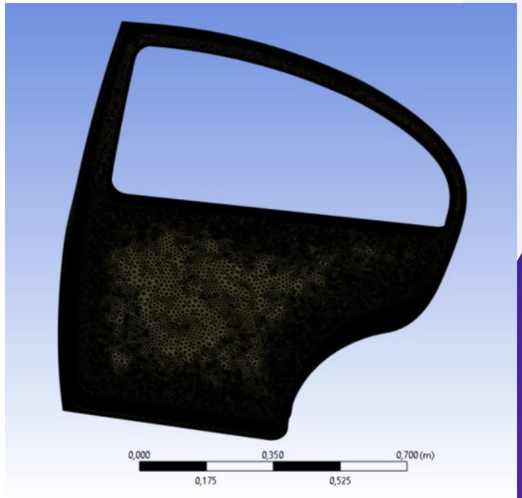


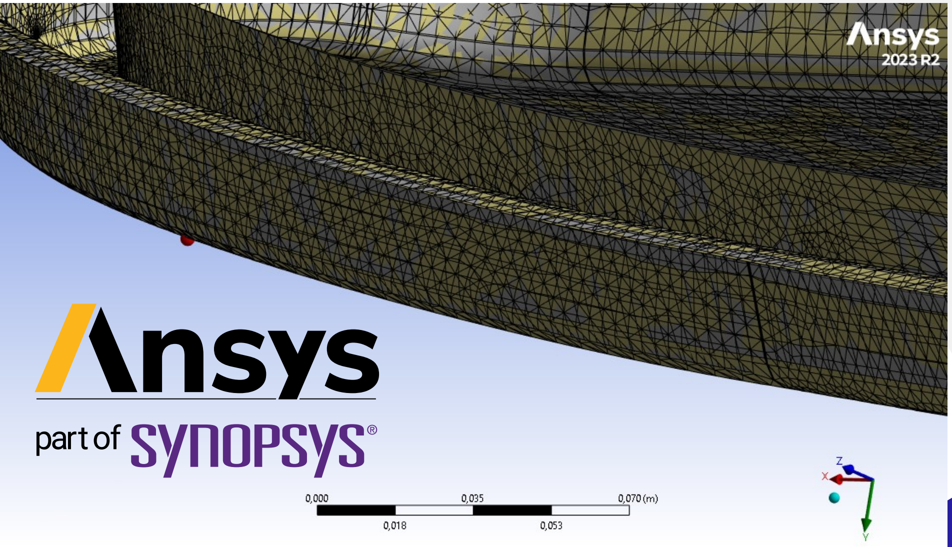
The clearance between the door and the body has to be carefully controlled to have a proper operation of the seal and a fulfillment of aesthetic requirements:

- This PoC was conducted for a car manufacturer during a technology scouting process.
- Both the CAD and the CAE model (FEA) are morphed onto the As Built Shape.
- RBF mesh morphing was successfully demonstrated using a synthetic shape (surface target).

Case study 1: Car door







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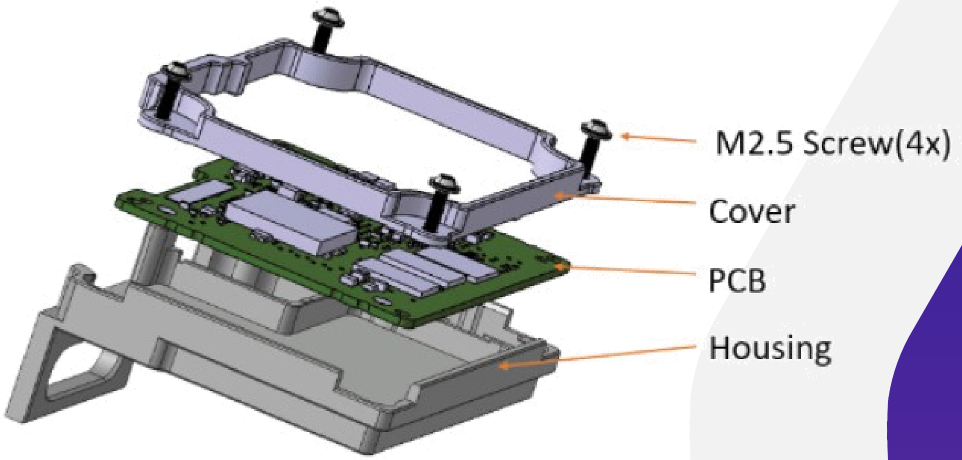
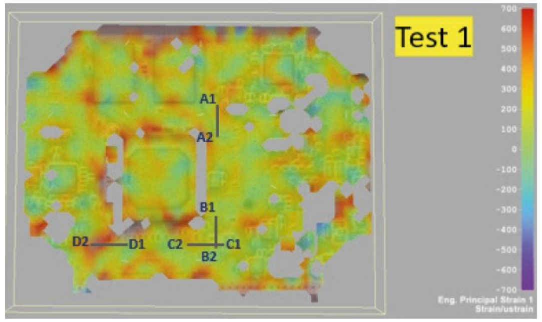
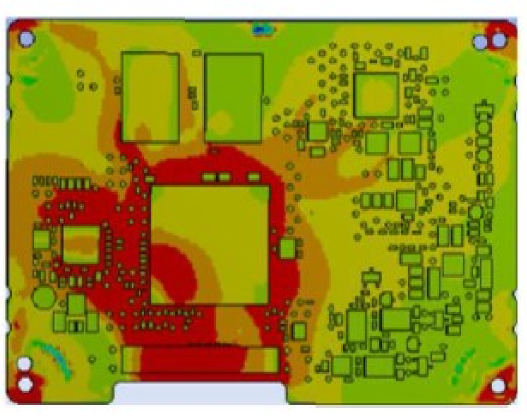
Case study 2: Flat PCB



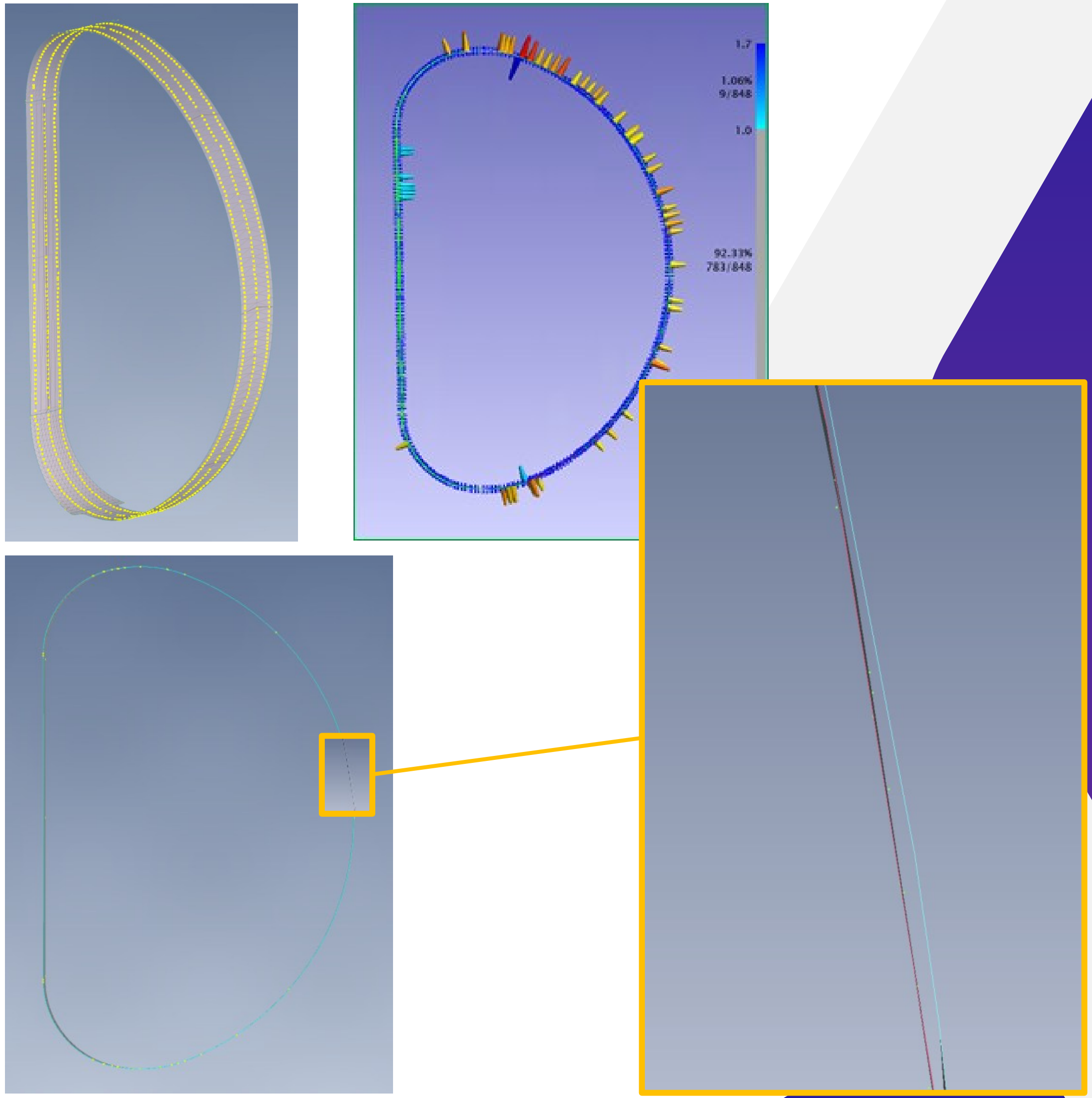




The PCB is designed as a flat board. However the assembly of the electronic components introduce some distortion that are responsible of pre-stress once mounted in the housing:

- The surveyed points are available as x-y map of heights.
- The high fidelity FEA model (6 millions nodes) is warped according to the surveyed data.
- The thermal fatigue cracks observed experimentally are predicted.

Case study 3: TF coil housing

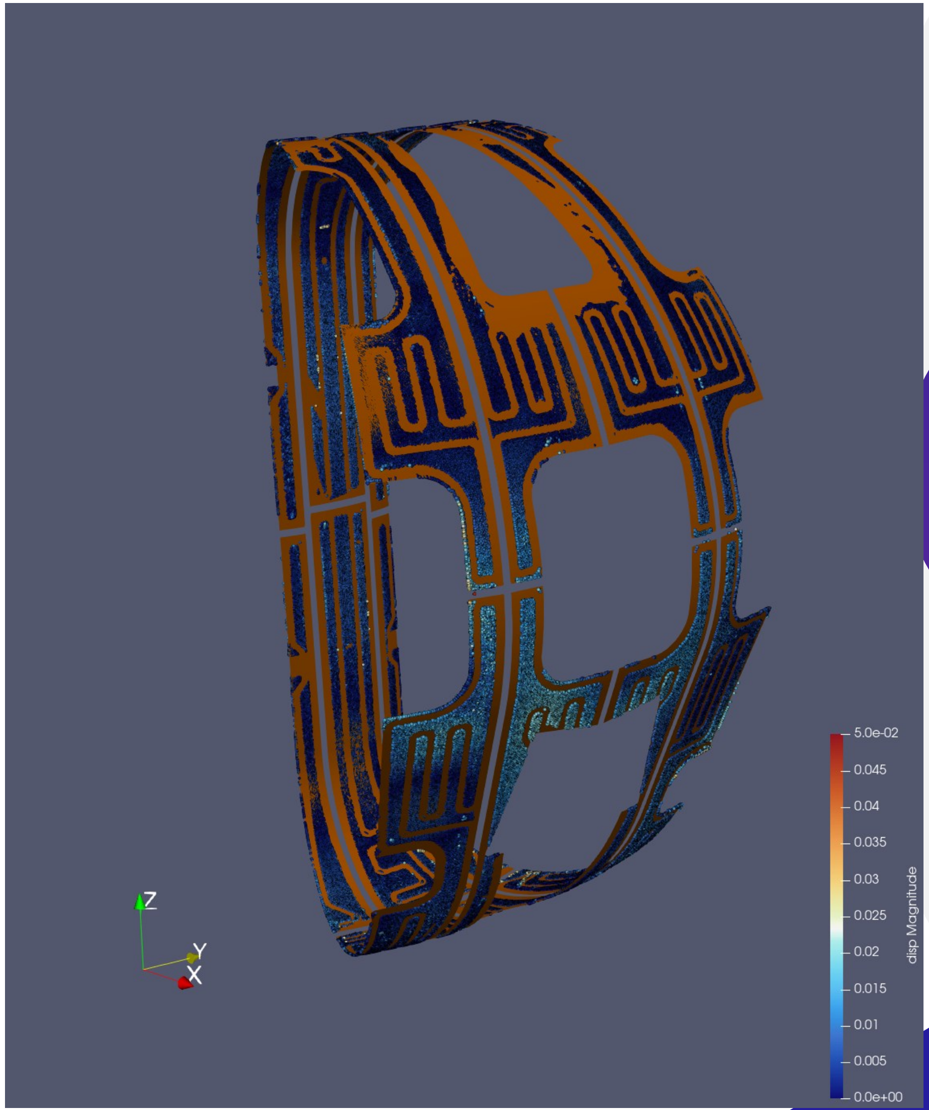


A reconstruction of the inner surface of the TF coil housing has been performed according to the following process:

- Nominal CAD surfaces along with the surveyed points are provided as input.
- The surfaces are warped producing a CAD representation and a tessellated STL representation of the As Built morphology.
- The resulting geometrical model has a good match with the input cloud and has been validated within the metrology software.

Pompa, E., Leonard, P., Popa, T., Reccia, L., Biancolini, M. E., D'Amico, G., & Fuentes, F. J. (2025). Validation of vacuum vessel thermal shield deformation via finite elements and morphing techniques based analysis. *Fusion Engineering and Design*, *215*, 114937.

Case study 4: VV thermal shield

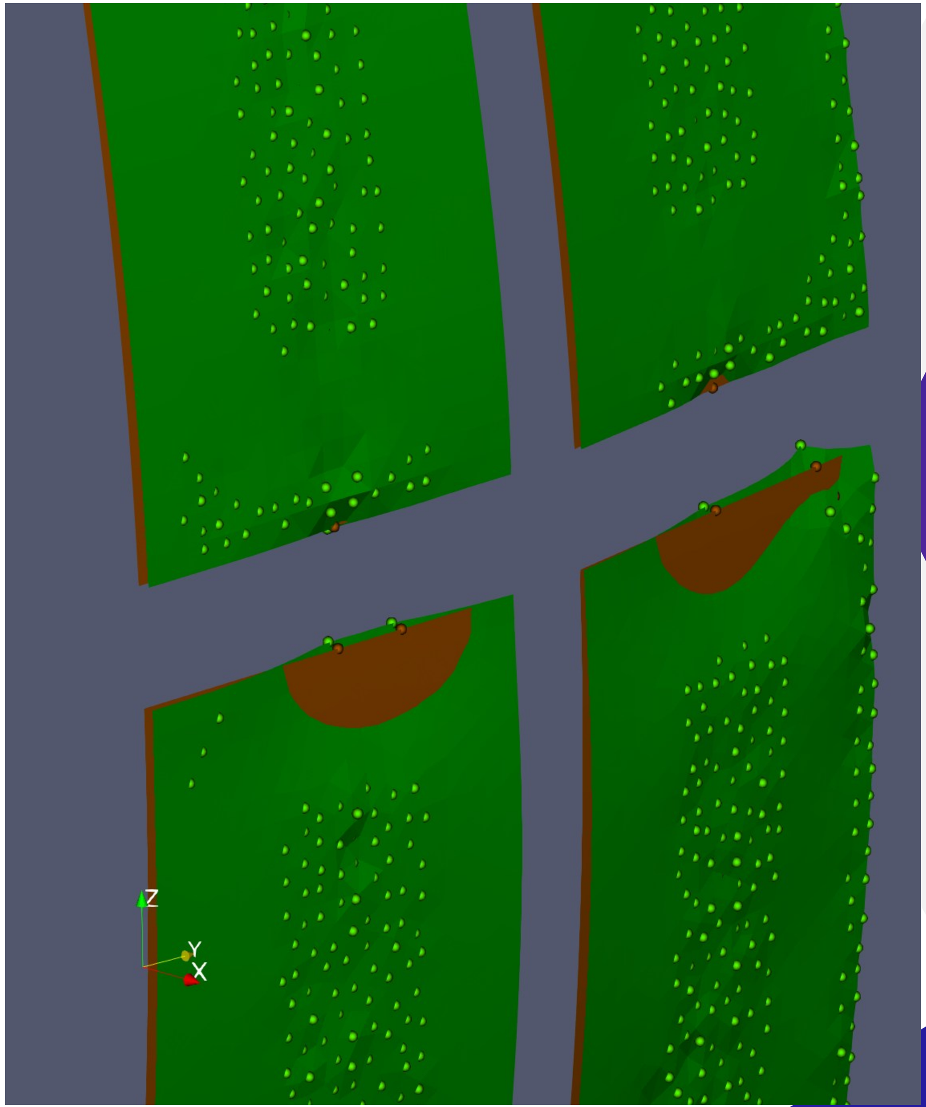


A reconstruction of the VV thermal shield is on progress according to the following process:

- A cloud of surveyed points (2139589) aligned with the CAD is provided as input.
- The cloud is decimated (2.5 cm 56192 points) and then processed by a batch brep projection on the CAD (inverse projection method).
- A fine STL tessellation is produced to receive the morphing.
- Reconstructed NURBS patches faithfully reproduce the input cloud
- Morphed brep are then trimmed using the nominal CAD edges

Pompa, E., Porziani, S., Groth, C., Chiappa, A., D'Amico, G., Costa, E., ... & Biancolini, M. E. (2021, February). CAD model update on as-built geometries with morphing technique: ITER winding pack. In *IOP Conference Series: Materials Science and Engineering* (Vol. 1038, No. 1, p. 012082). IOP Publishing.

Case study 4: VV thermal shield



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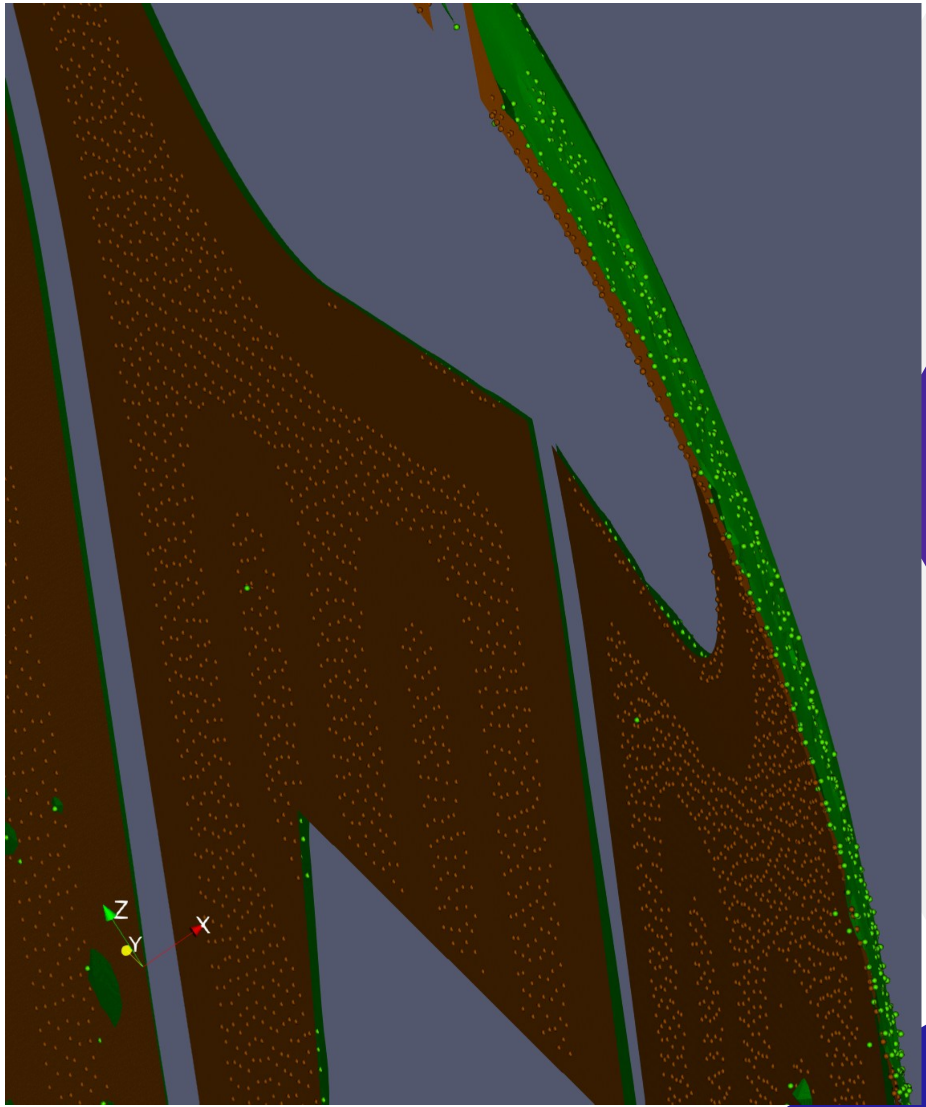

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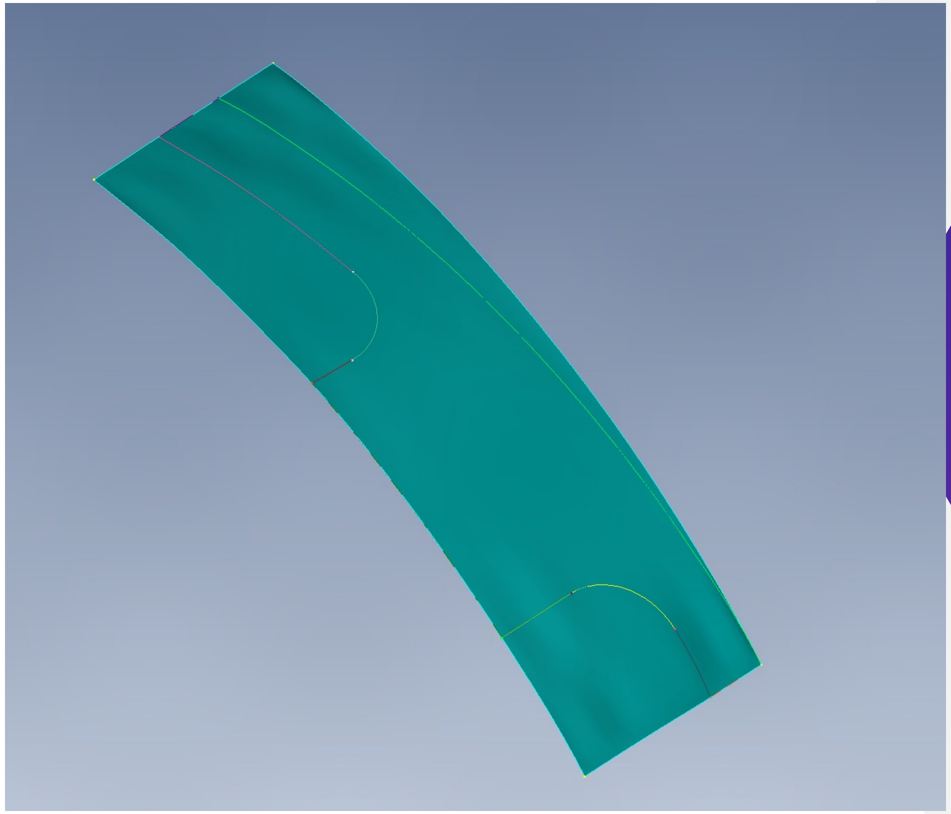

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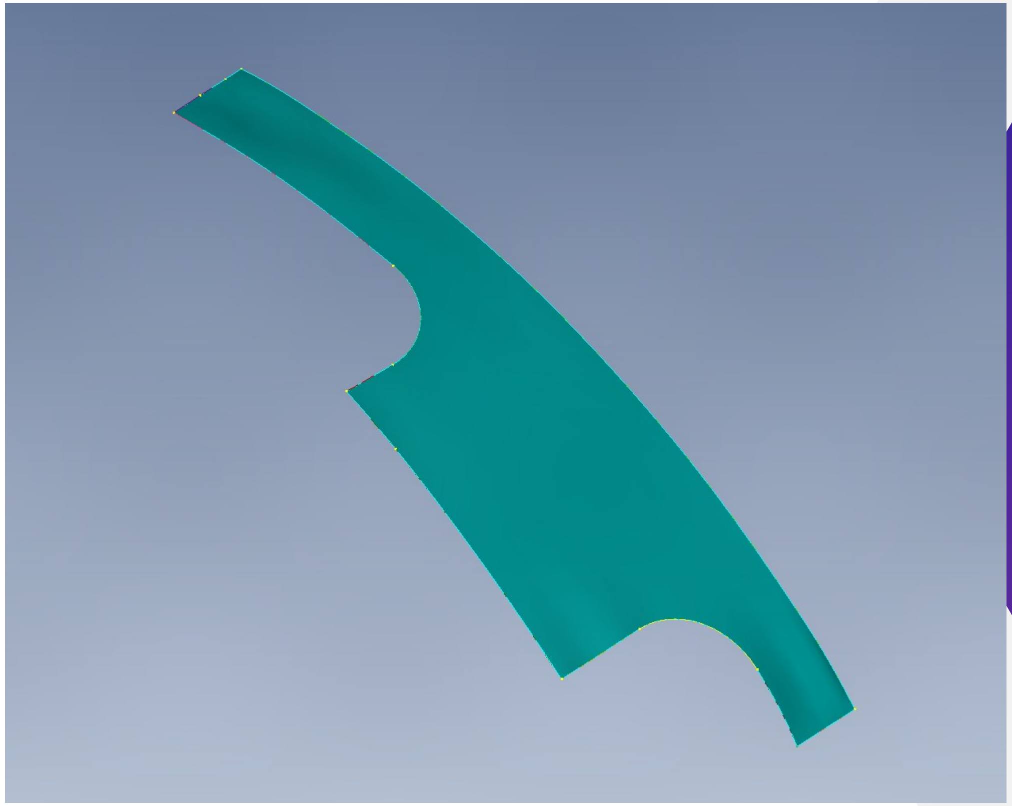

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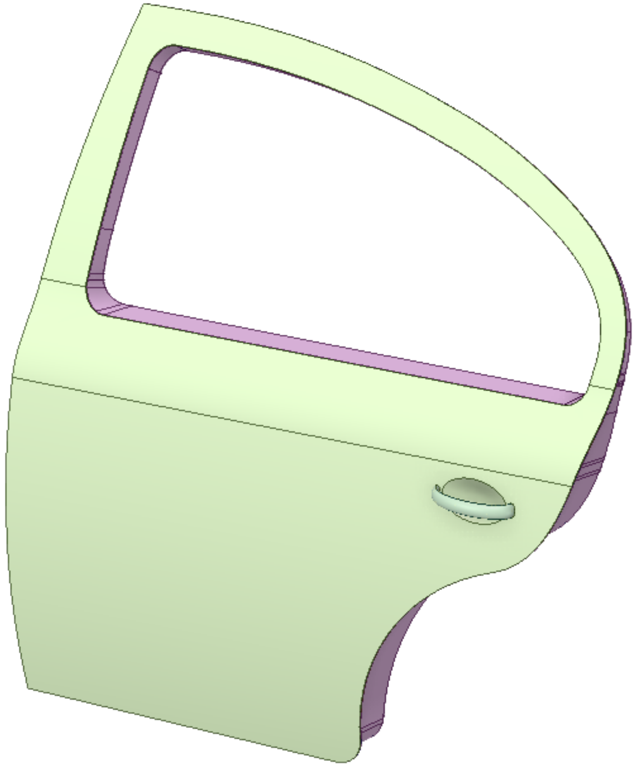
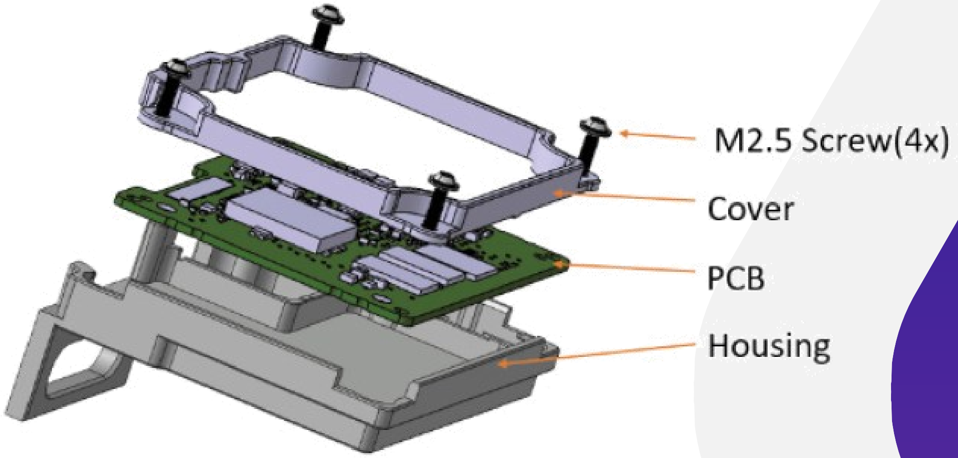


The clearance between the door and the body has to be carefully controlled to have a proper operation of the seal and a fulfillment of aesthetic requirements:

- The PoC was a good demonstrator.
- It was conducted within Ansys Mechanical.
- Need for a specific solution to bridge CAD and CAE.

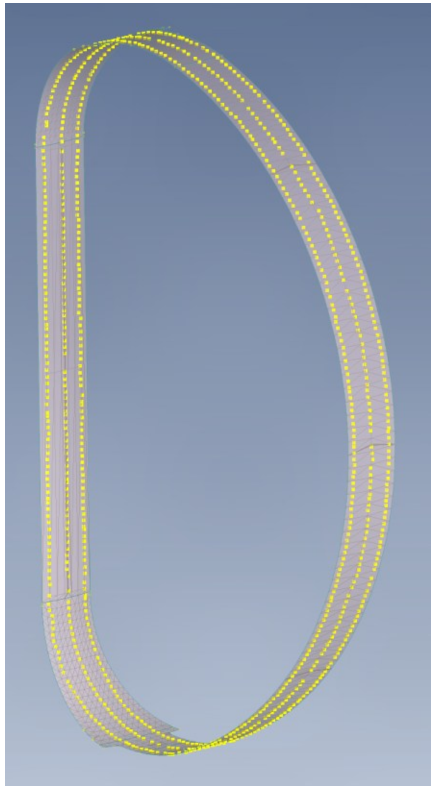
Case study 2: Flat PCB



The PCB is designed as a flat board. However the assembly of the electronic components introduce some distortion that are responsible of pre-stress once mounted in the housing:

- This could become an on-line quality control.
- A metamodel for surface fragility evaluation.
- Statistical Shape Modeling.

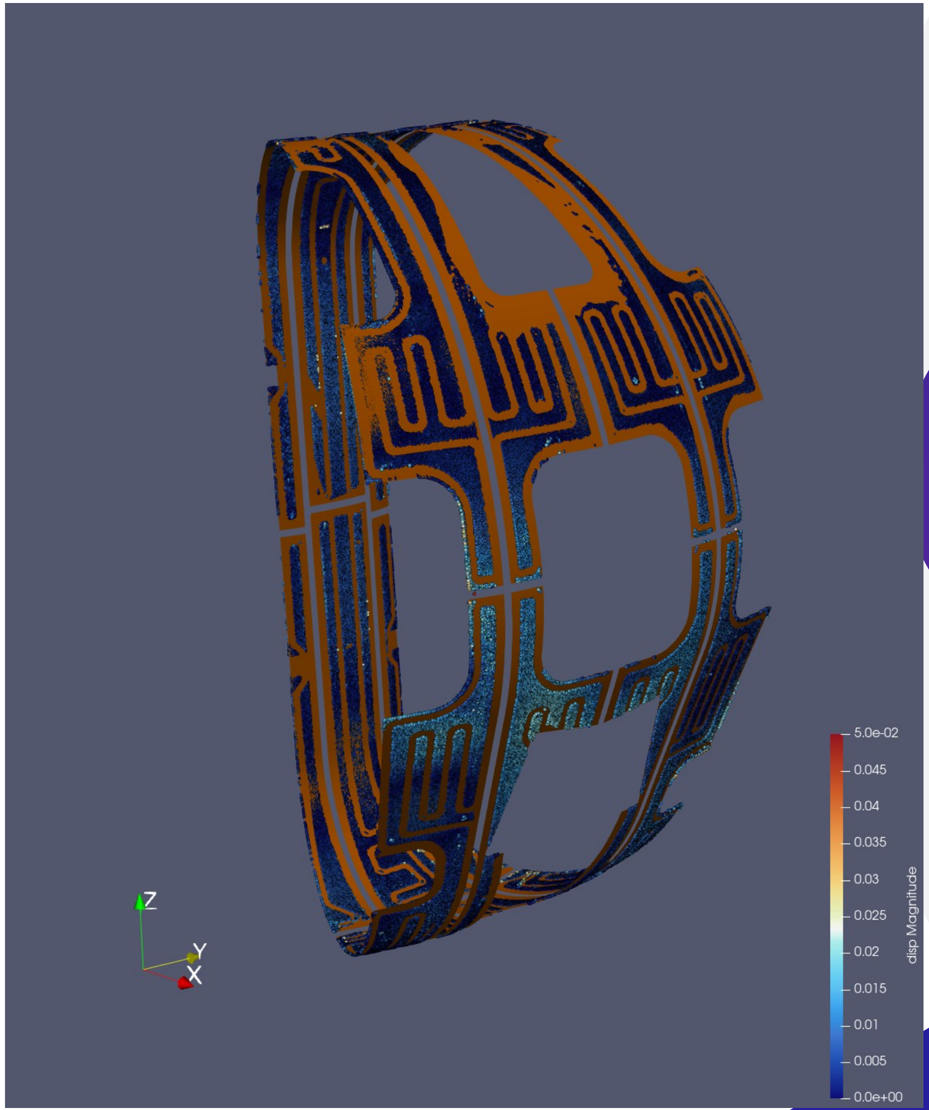
Case study 3: TF coil housing



A reconstruction of the inner surface of the TF coil housing has been performed according to the following process:

- Proven for STL tessellated surfaces.
- BREP?

Case study 4: VV thermal shield



A reconstruction of the VV thermal shield is on progress according to the following process:

- Support of the assembly process.
- Combined with full FEA and virtual measurements (FEA evaluated) to support assembly and maintenance.
- Would an integrated software solution combining metrology, CAD and CAE be useful?

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Q&A

Thank you for your attention

See you on 27th and 28th of January 2026 in Barcelona
To share with us your ideas

Contact us:
mre-workshop@f4e.europa.eu

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