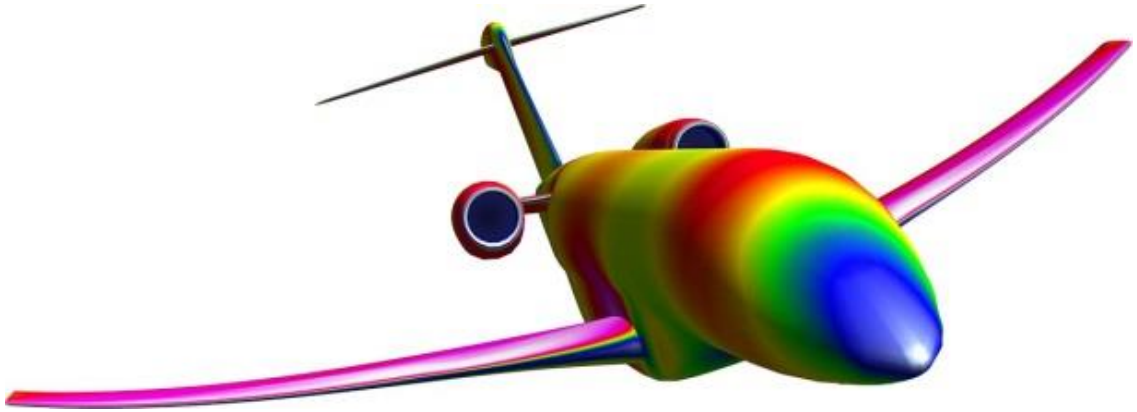
High Fidelity FSI analysis methods and their validation within the EU RIBES project



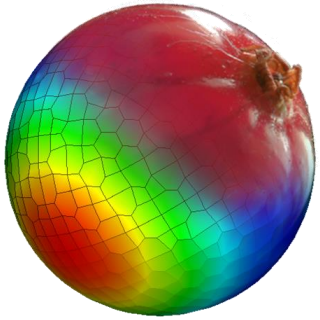
Università di Roma Tor Vergata

Ubaldo Cella

Flexible Engineering

Rome 14 December 2017

DESIGN METHODS™



RIBES

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

SEVENTH FRAMEWORK PROGRAMME

Clean Sky

Programme:
Clean sky joint undertaking
Topic:
Green Regional Aircraft

Objectives of RIBES

- Development of a **load mapping procedure** for 2 ways FSI analysis tools
- Definition of an **aeroelastic experimental campaign**
- Development of a **structural optimization procedure**

Partners

Università di Roma Tor Vergata

(rbf-morph)™

Welcome to the World of Fast Morphing!

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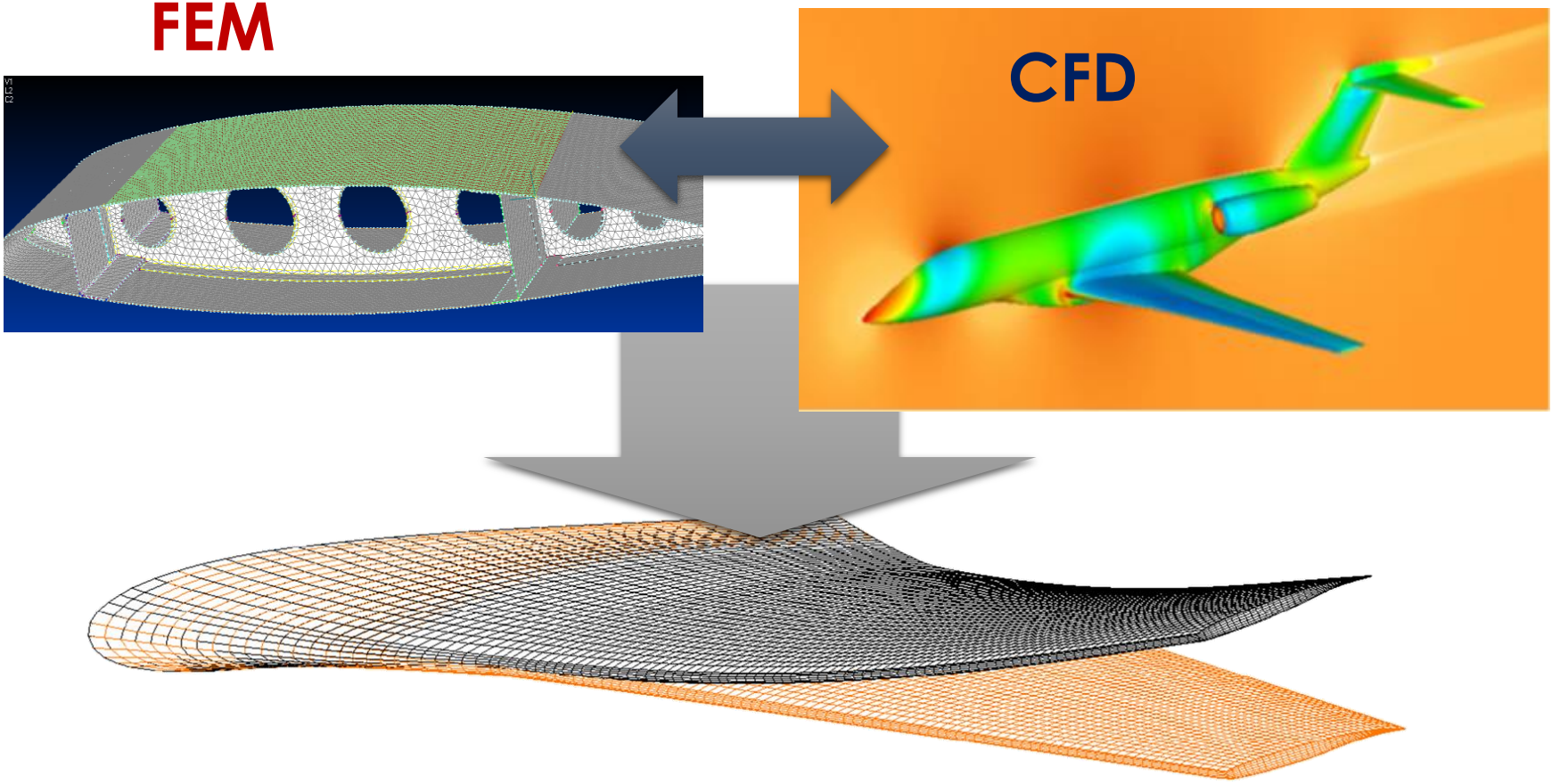
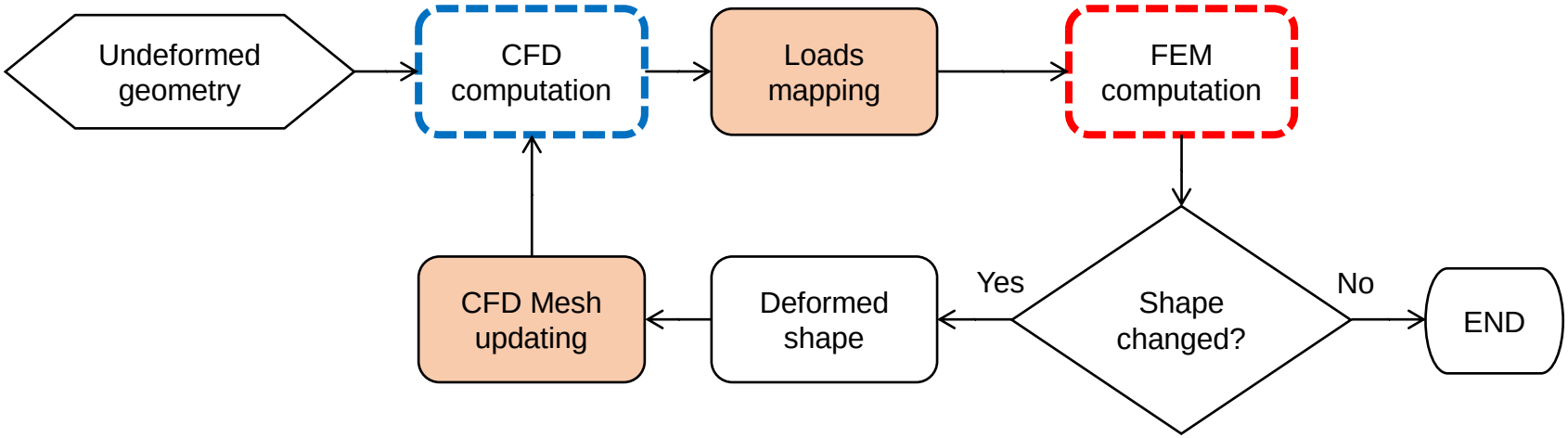
DESIGN METHODS™

Aerospace Engineering - www.designmethods.aero

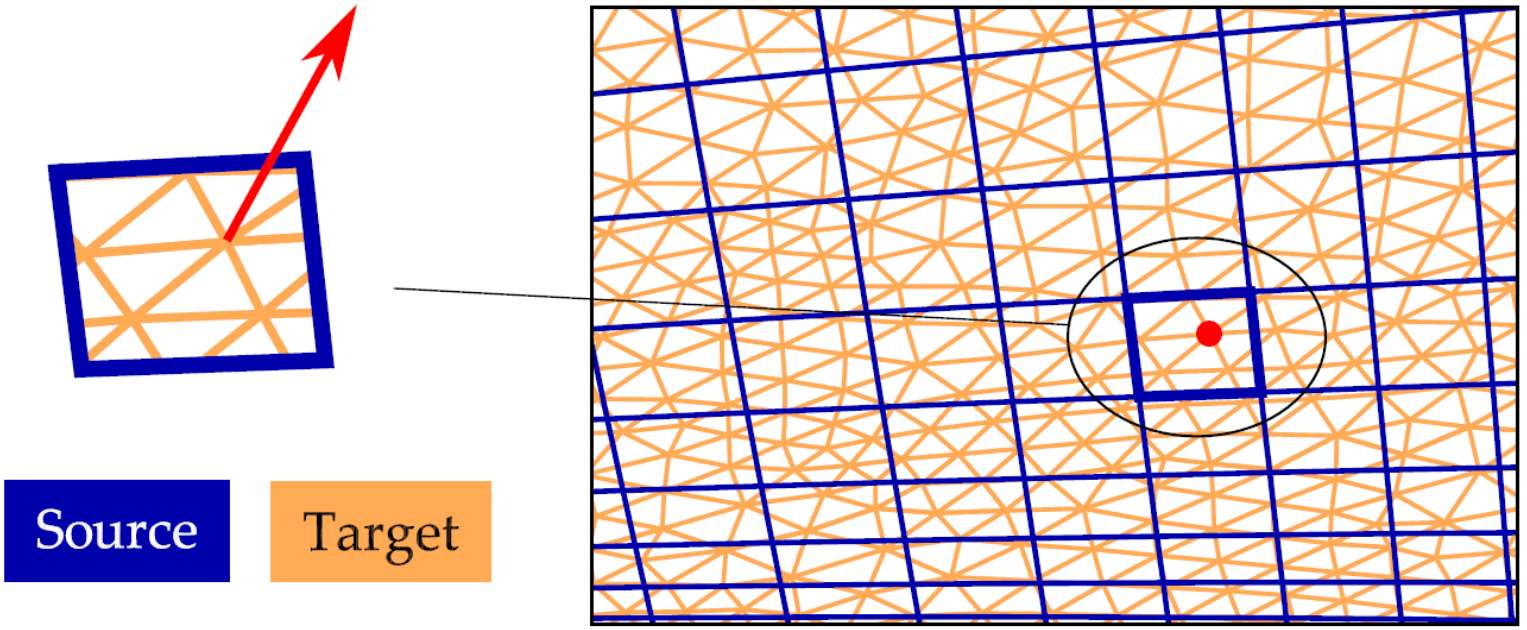
High fidelity FSI analyses



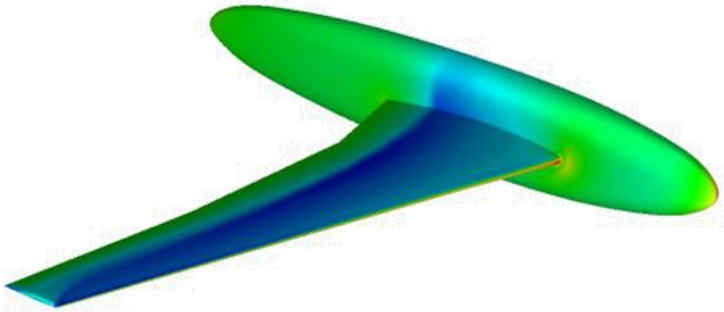
2 ways FSI procedure



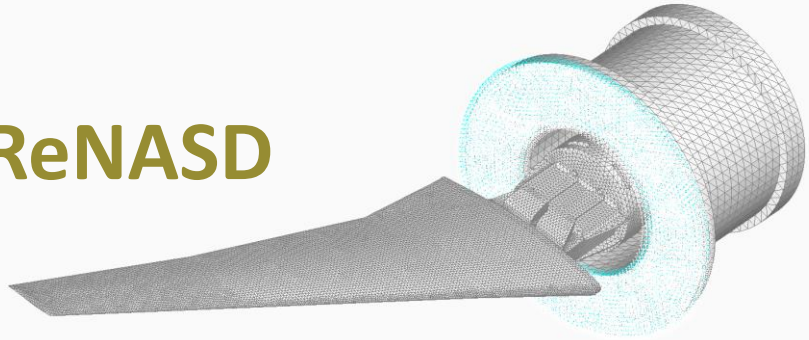
Load mapping problem



Load mapping errors



HiReNASD



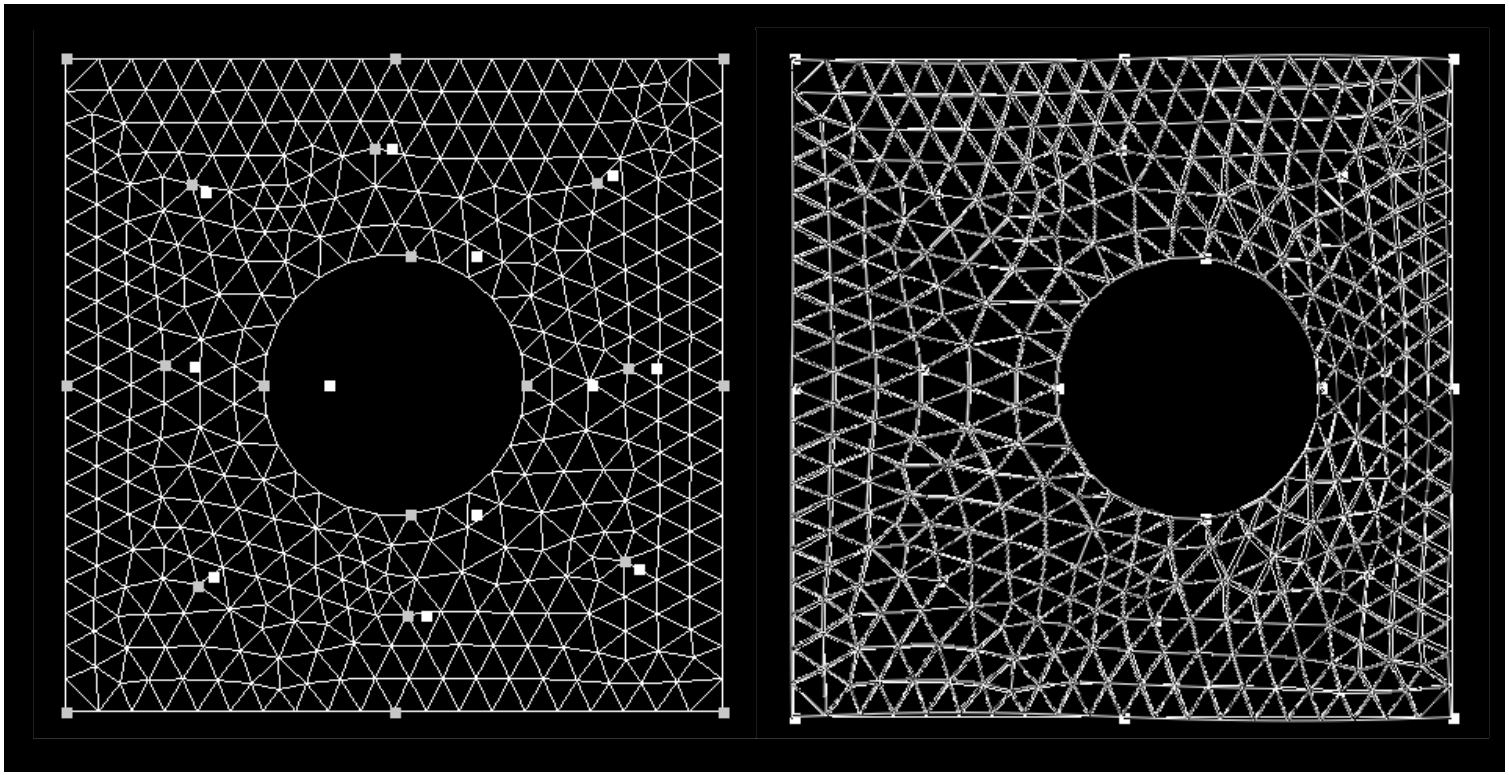
% errors on forces resultants components

% ERROR	R_X [N]	R_Y [N]	R_Z [N]
NO CORRECTION	47.3%	6.6%	1.0%
RIBES CORRECTION	0%	0%	0%

% errors on moments resultants components

% ERROR	M_X [Nm]	M_Y [Nm]	M_Z [Nm]
NO CORRECTION	13.1%	13.8%	27.8%
RIBES CORRECTION	0.8%	0.11%	0.38%

Mesh morphing



RBF for mesh morphing

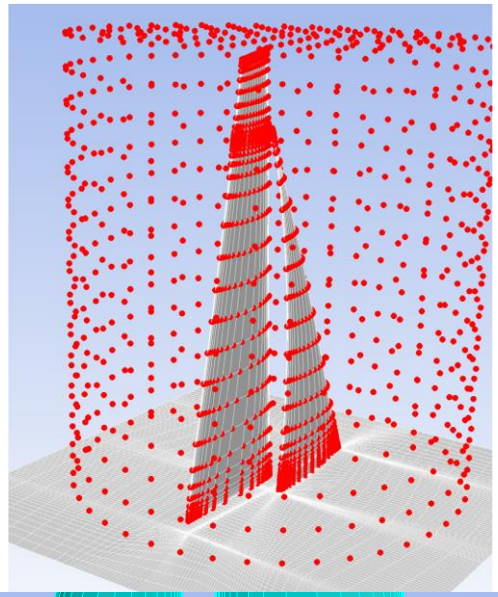
- **Radial Basis Functions** (RBF) can be used to drive mesh morphing (smoothing) from a list of source points and their displacements.
  - Surface shape changes (exact nodes control)
  - Volume mesh smoothing.
- RBF are recognized to be one of the **best mathematical tool** for mesh morphing.

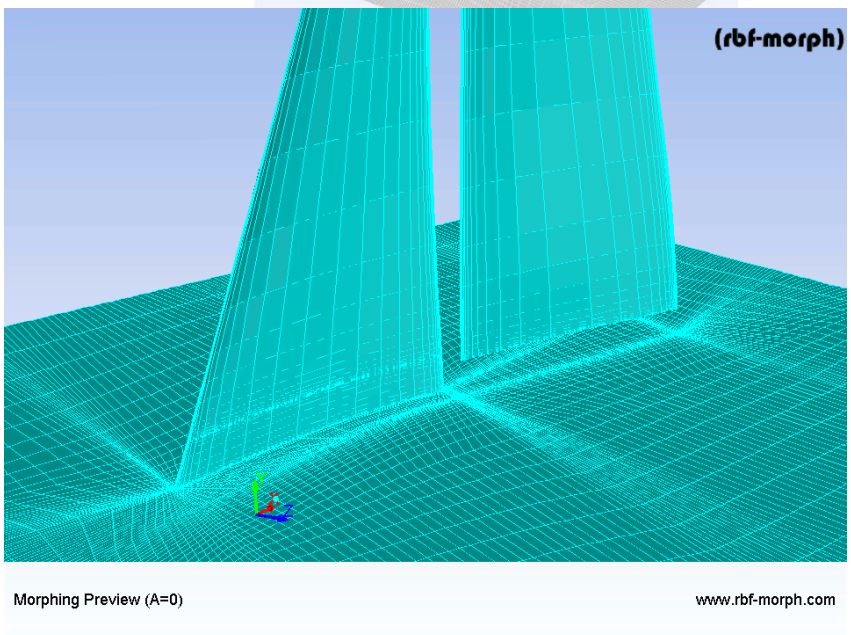
RBF mesh morphing

- Main advantages
  - No re-meshing
  - Can handle any kind of mesh
  - Can be integrated in the CFD solver
  - Highly parallelizable
  - Robust process
- Main disadvantage
  - Computationally expensive (HPC for large grids)

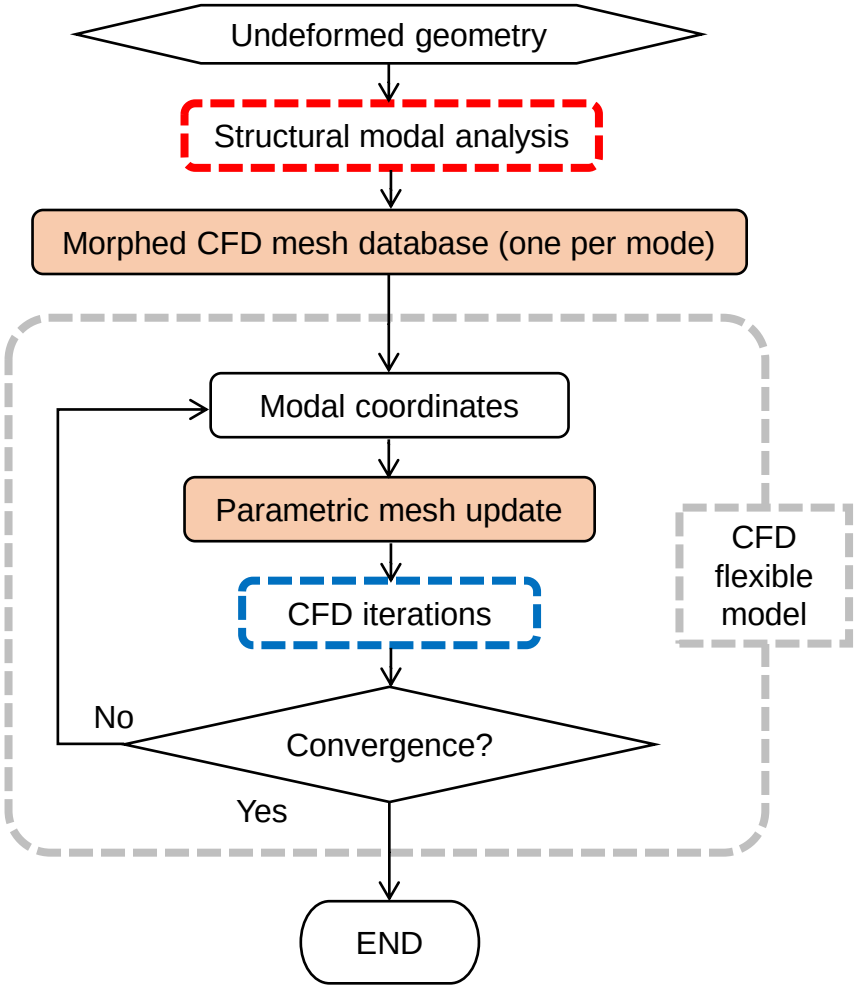
RBF Morph tool

- Setup
  - Select fixed and moving walls by source points
  - Prescribe the displacements (or a combination of)
- Fitting
  - Solving the RBF system and storing the solution
- Smoothing
  - Application of the morphing action on surfaces and volume





Modal approach for FSI



Parametric mesh formulation

number of natural modes

nodal modes displacement

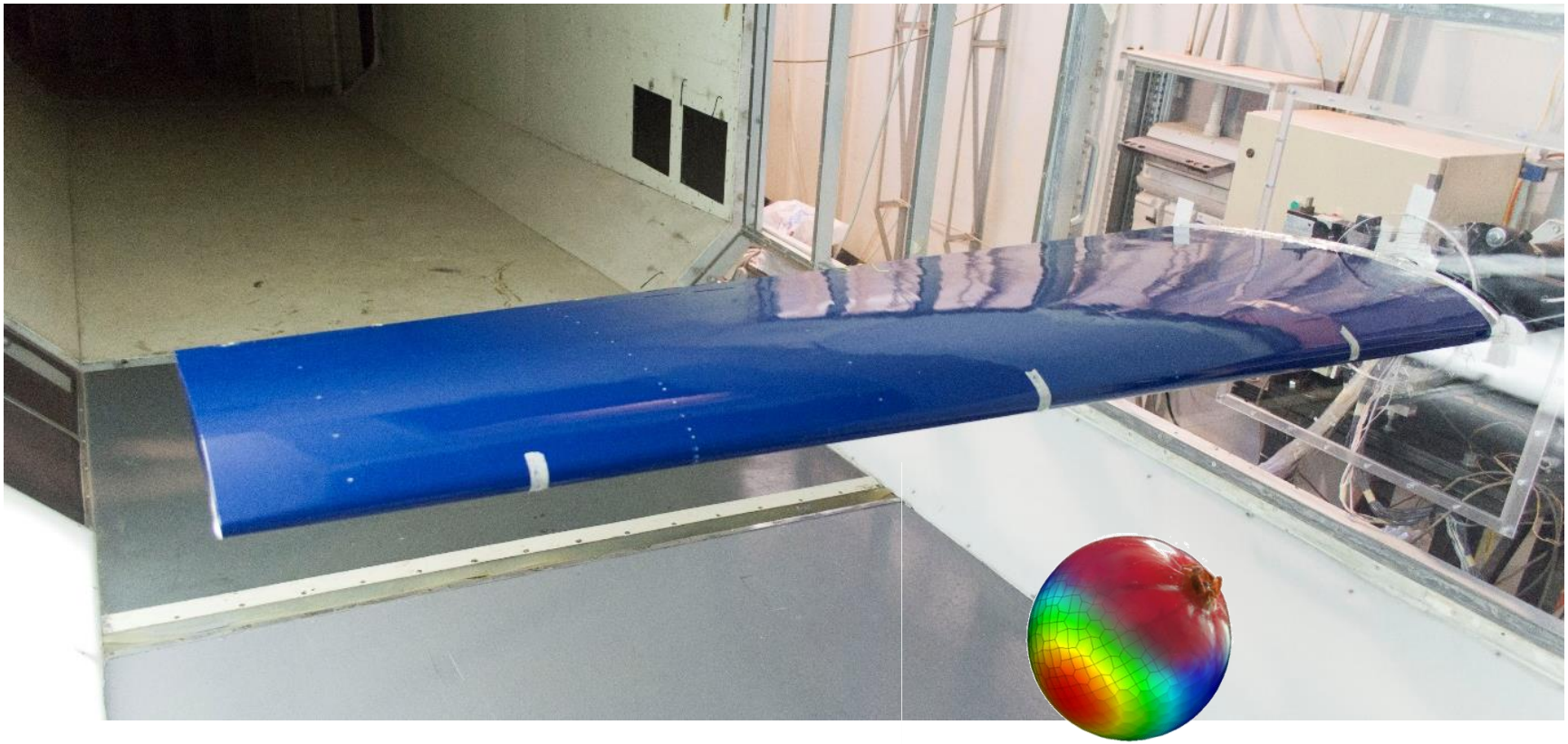
$$X_{CFD} = X_{CFD_0} + \sum_{i=1}^{k} q_i \Delta X_i$$

modal coordinate

Advantages and limits

- Main advantages
  - simpler numerical environments respect 2-way
  - Higher robustness
  - Mesh adaptation during computation (faster solution)
- Limits
  - Linear problems only (small displacements)
  - Uncertainness on the modal base dimension

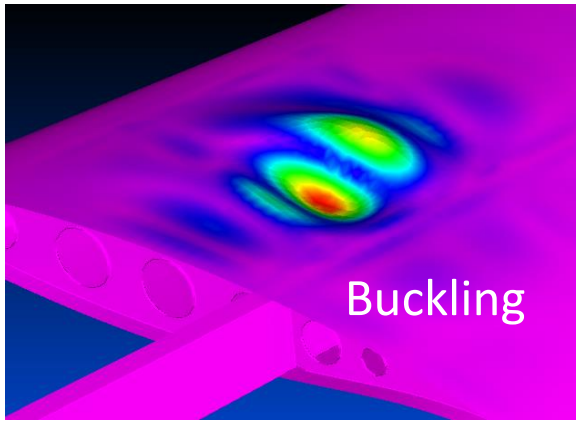
RIBES wing



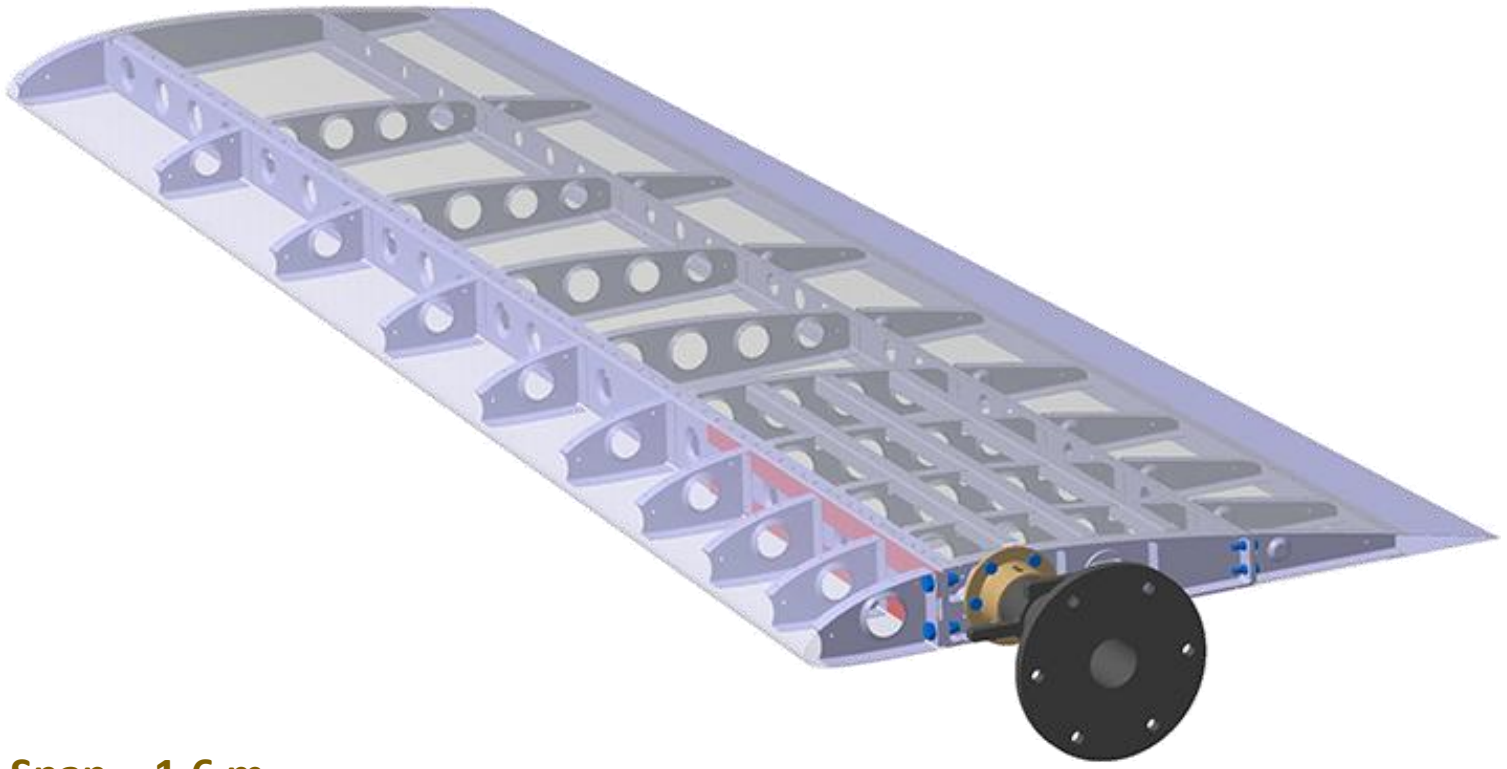
Critical points of design

- Structural similitude with a full scale wing
  - Impracticable manufacturing
- Conflicting high deformation requirement
  - Relatively higher thickness and lower loads
  - Difficult to load the spars and unload the skin

Panels stability was
the main design driver



Final test article details

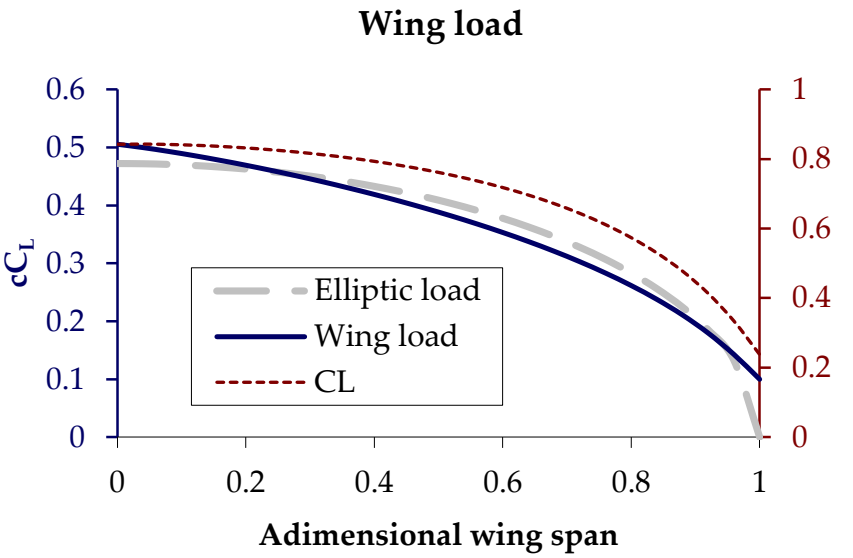


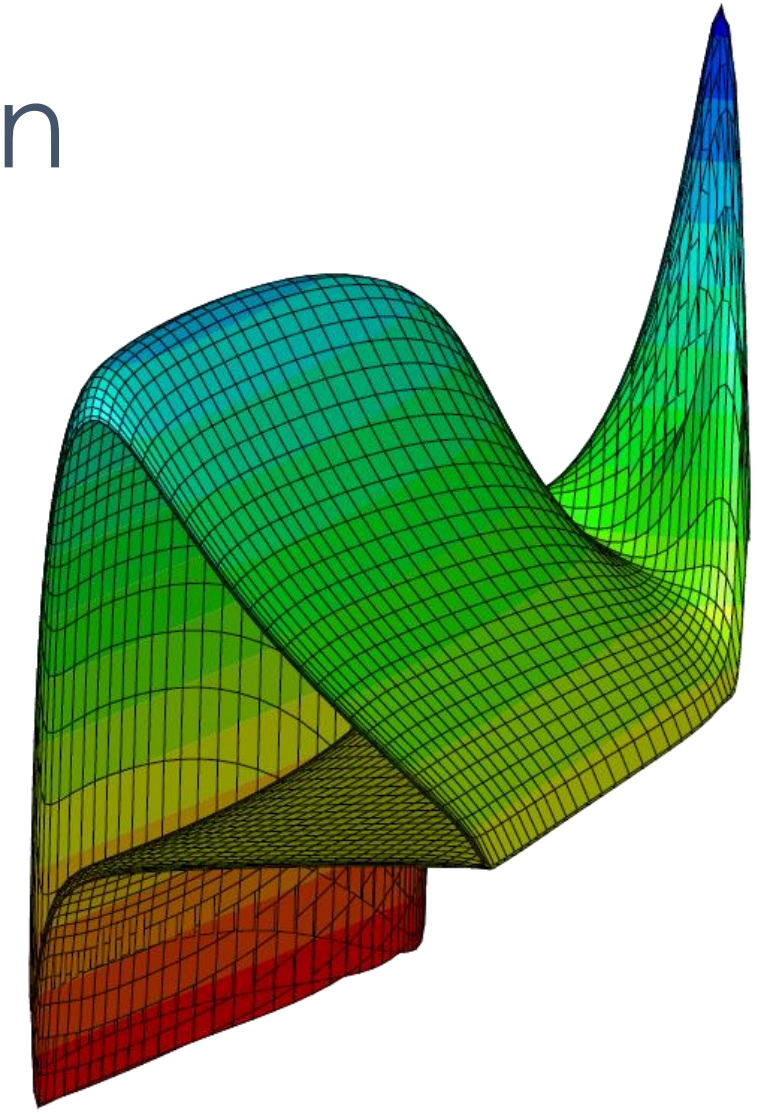
Span = 1.6 m

Material = AL2024T3 (Yeld Stress = 270 Mpa, Ultimate stress = 440 Mpa)

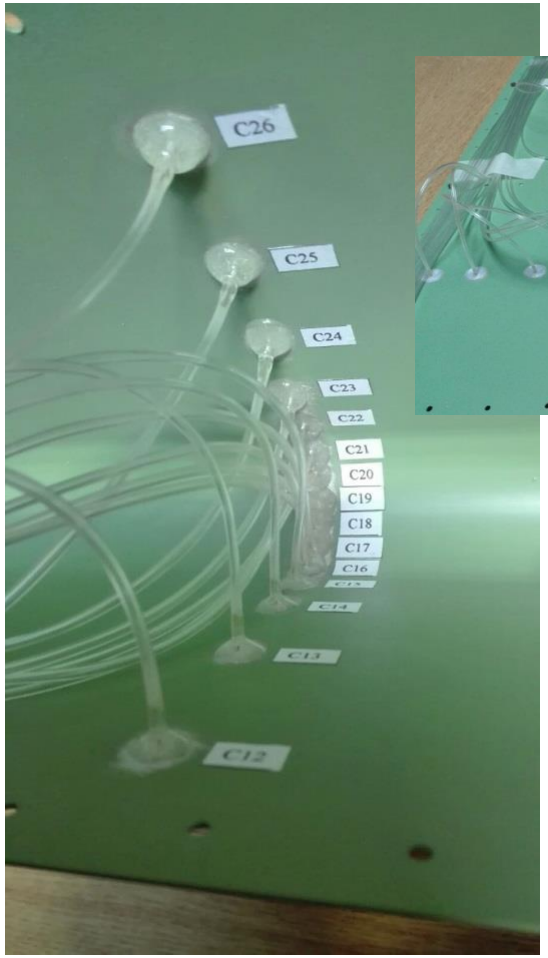
Load distribution

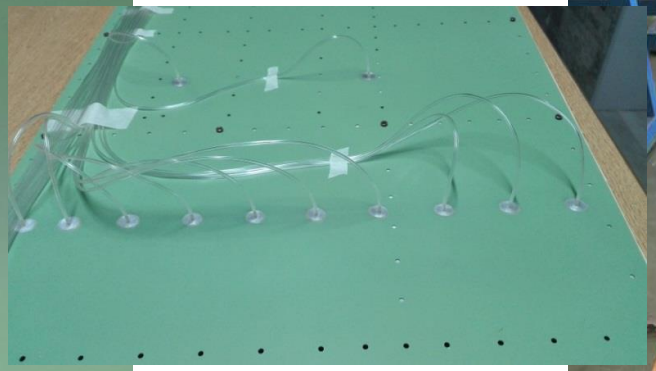
Alpha = 6 deg
V = 40 m/s
Lift = 67 Kg

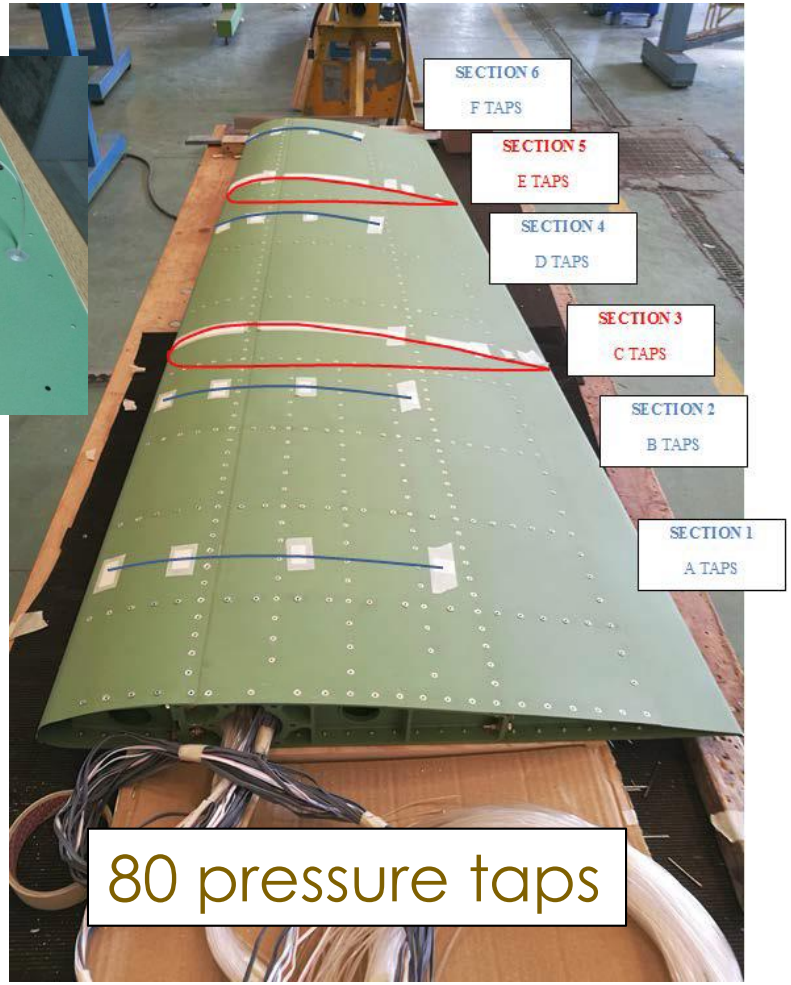




Pressure taps installation

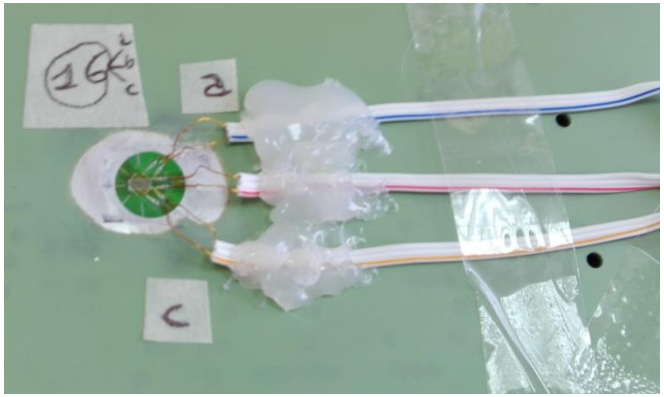


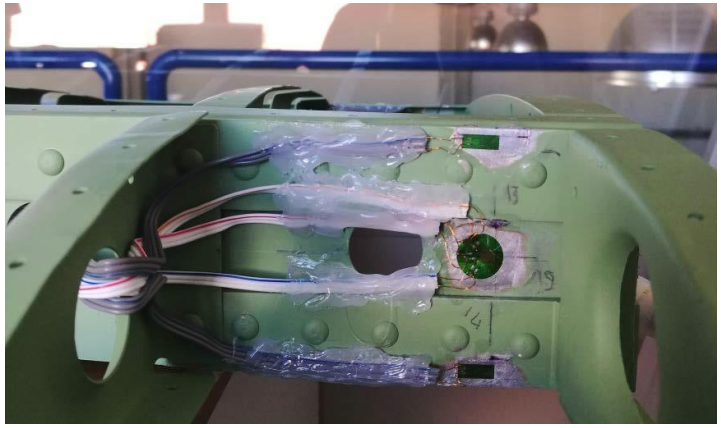




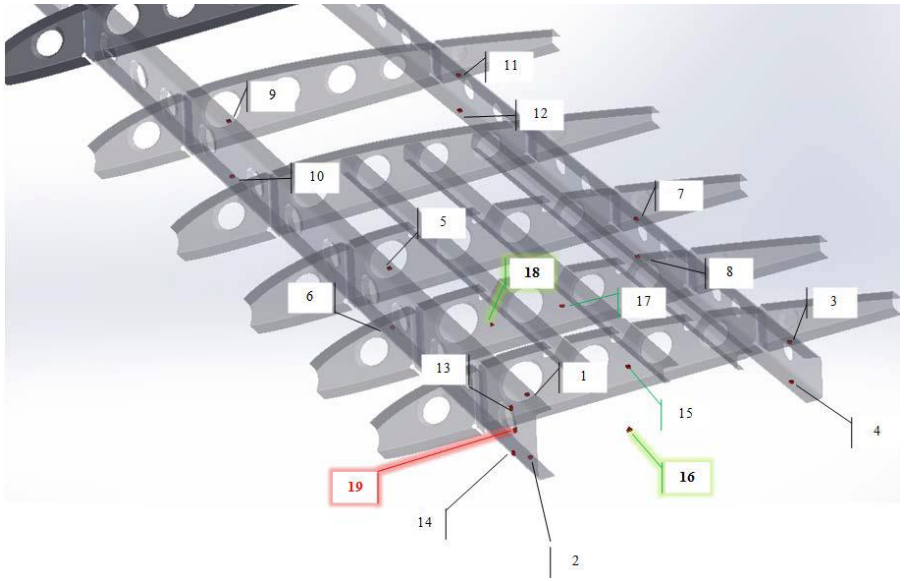
80 pressure taps

Strain gauges installation

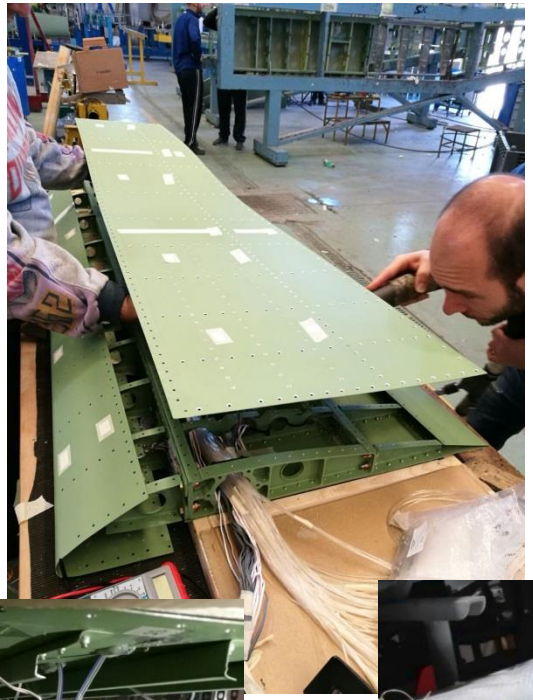


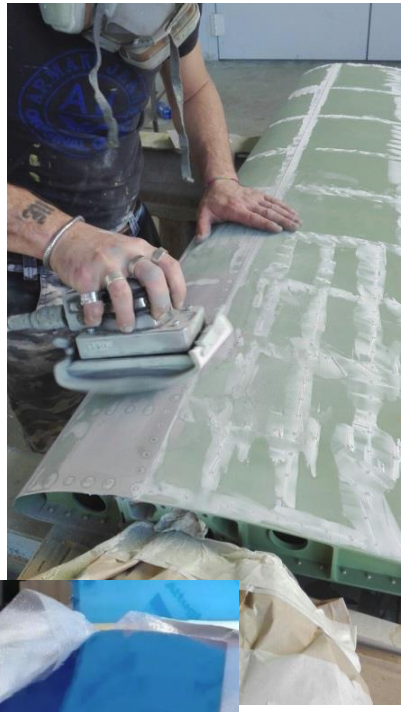


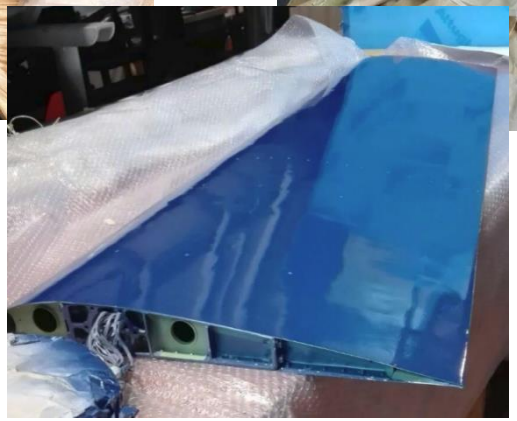
3 rosettes (three channels)
16 unidirectional



Model under construction

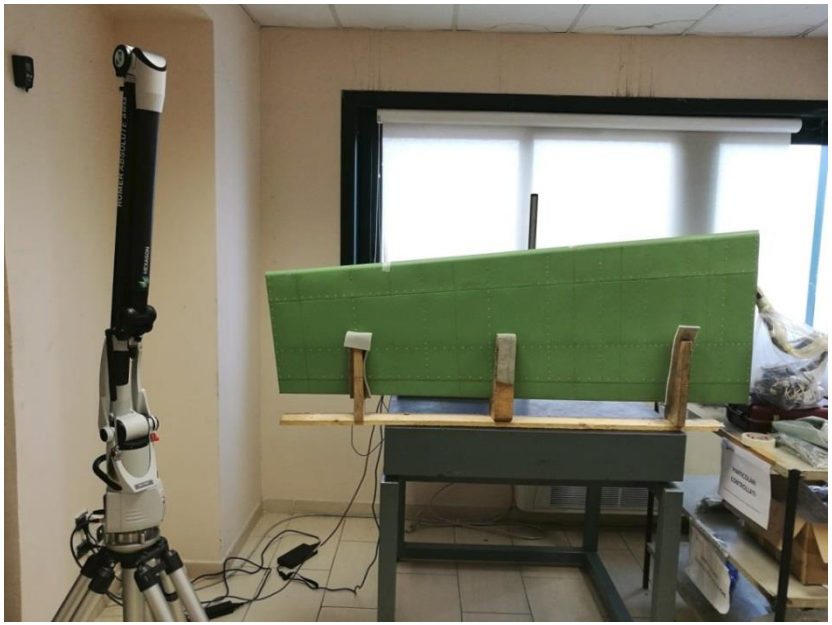




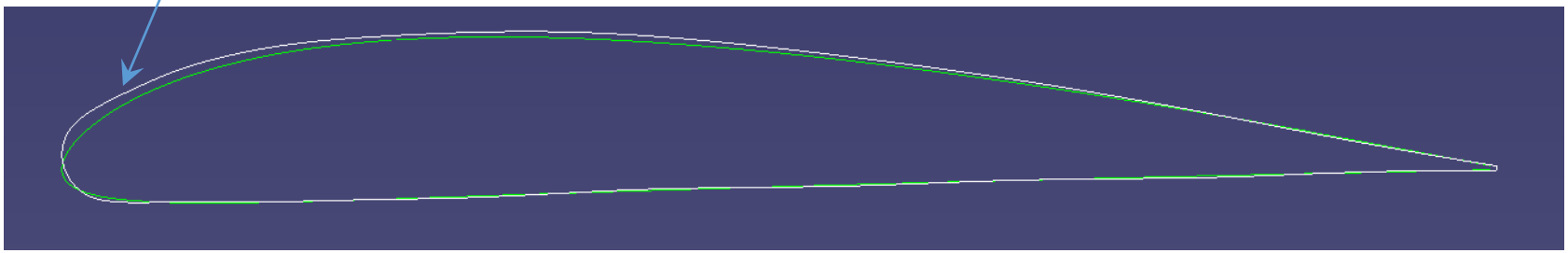


Measured geometry

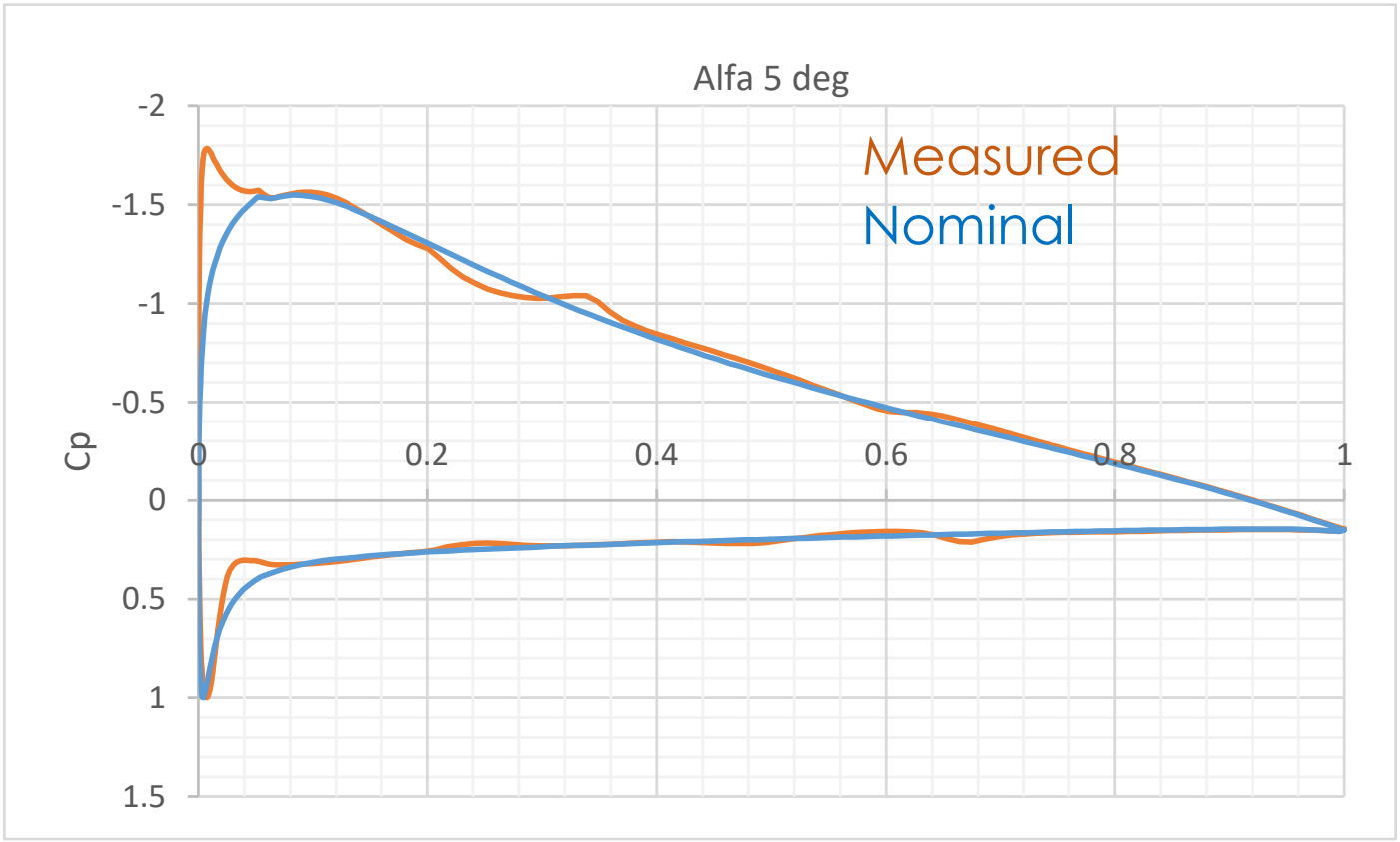
model measured
by **HEXAGON**
metrology
electronic harm



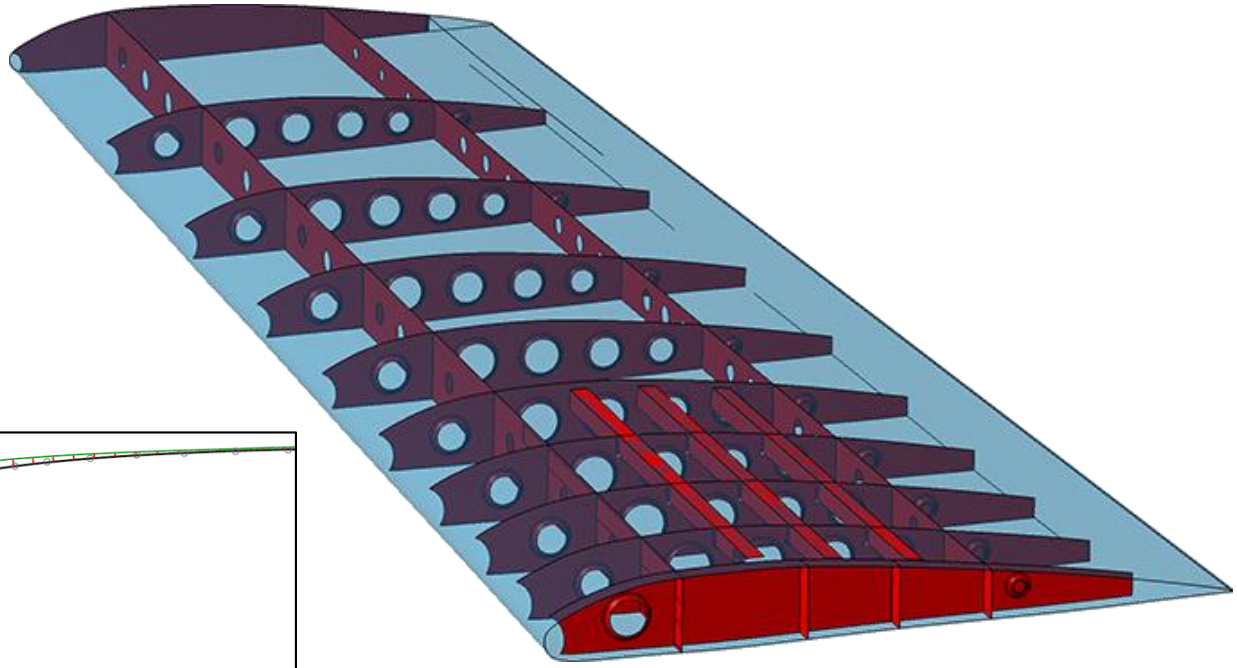
measured

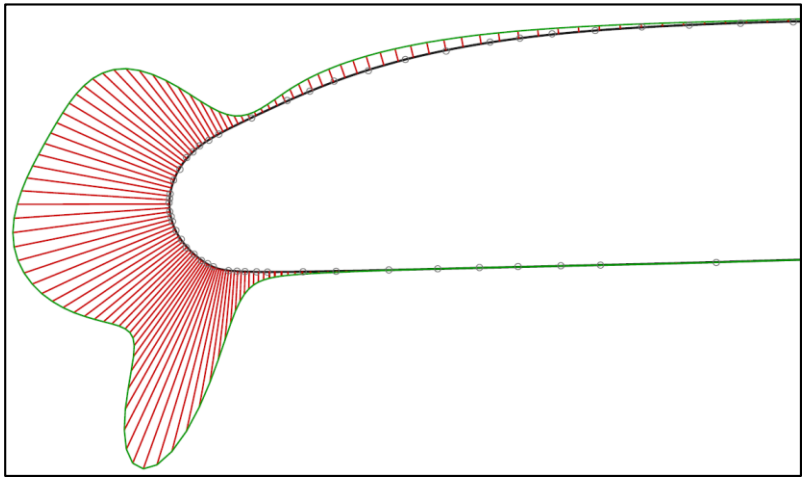


Effects on aerodynamics

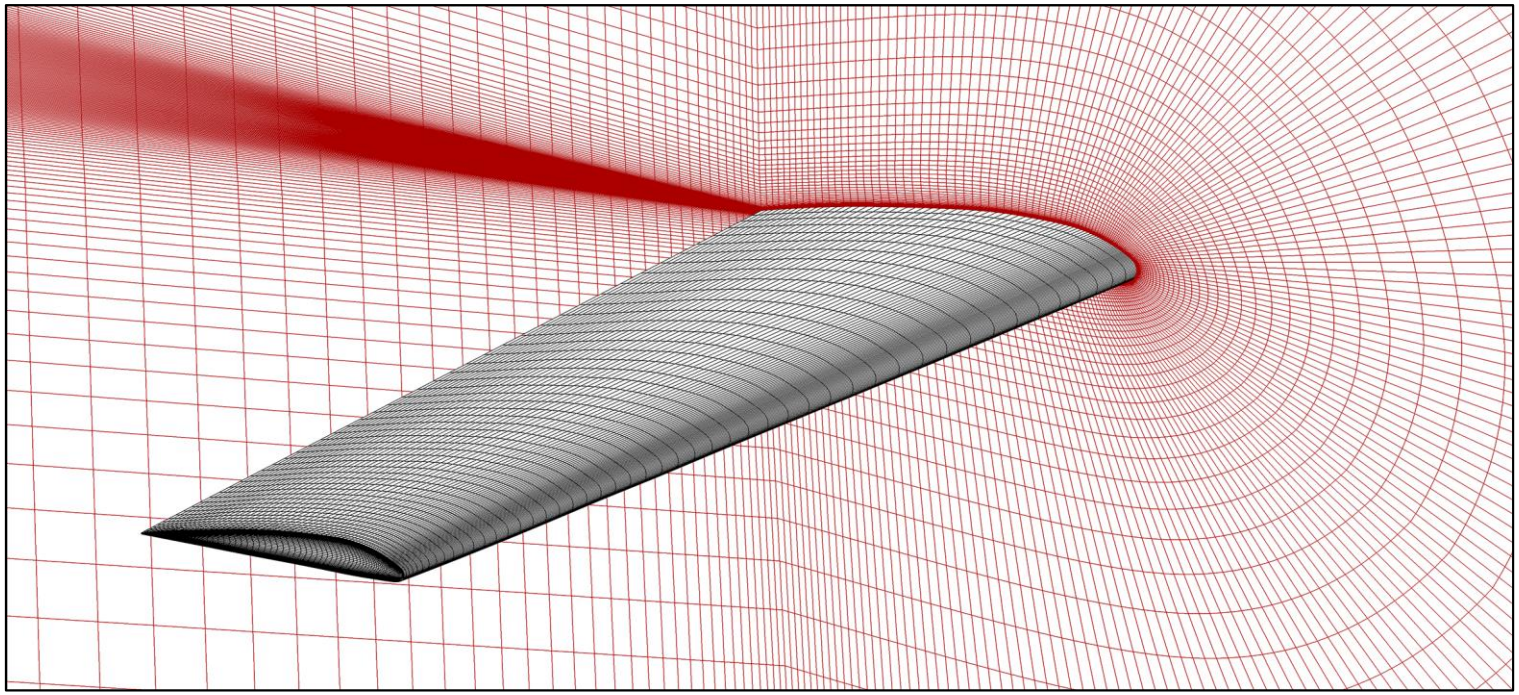


CAD reconstruction



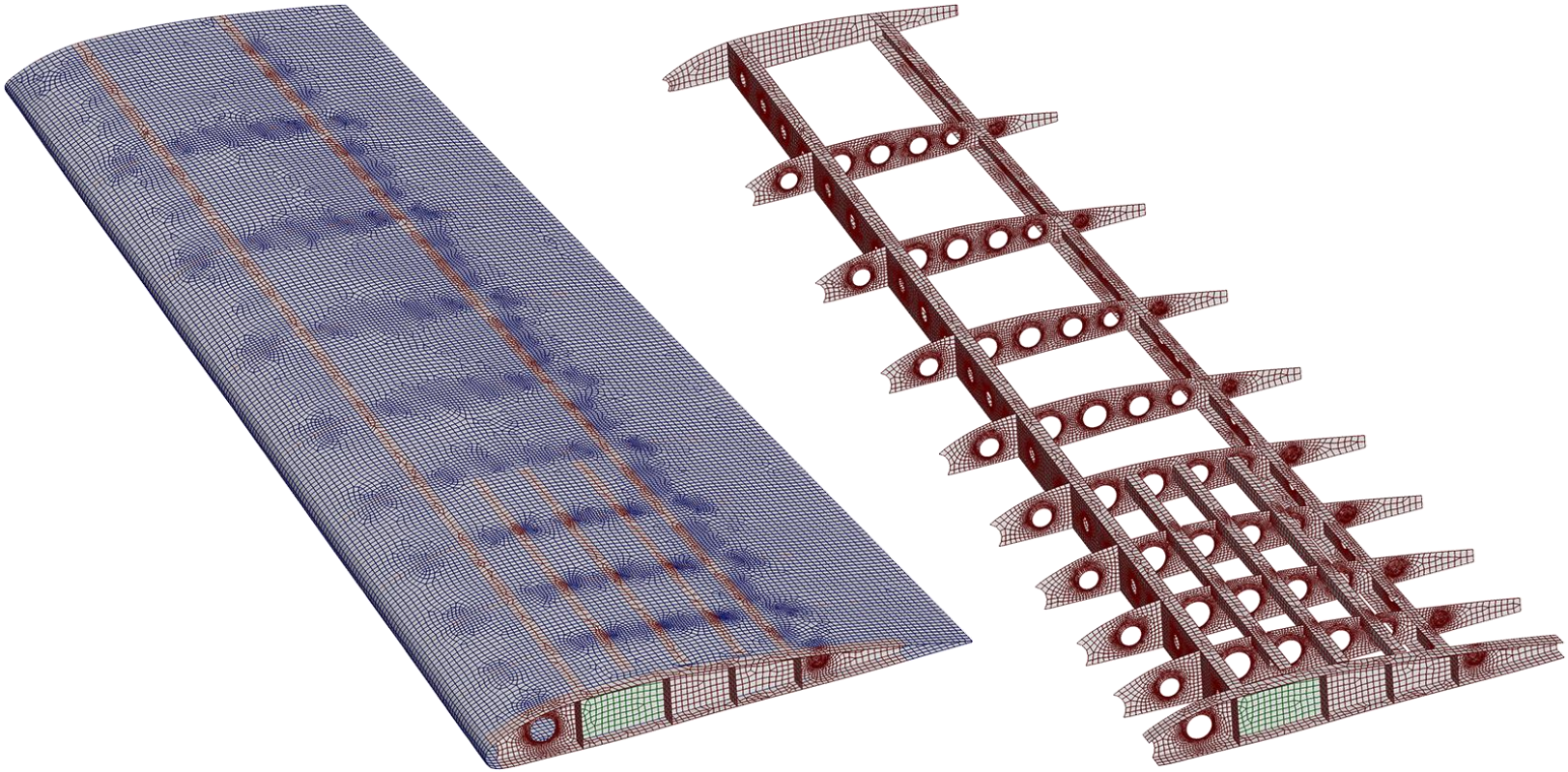


Free flight CFD domain



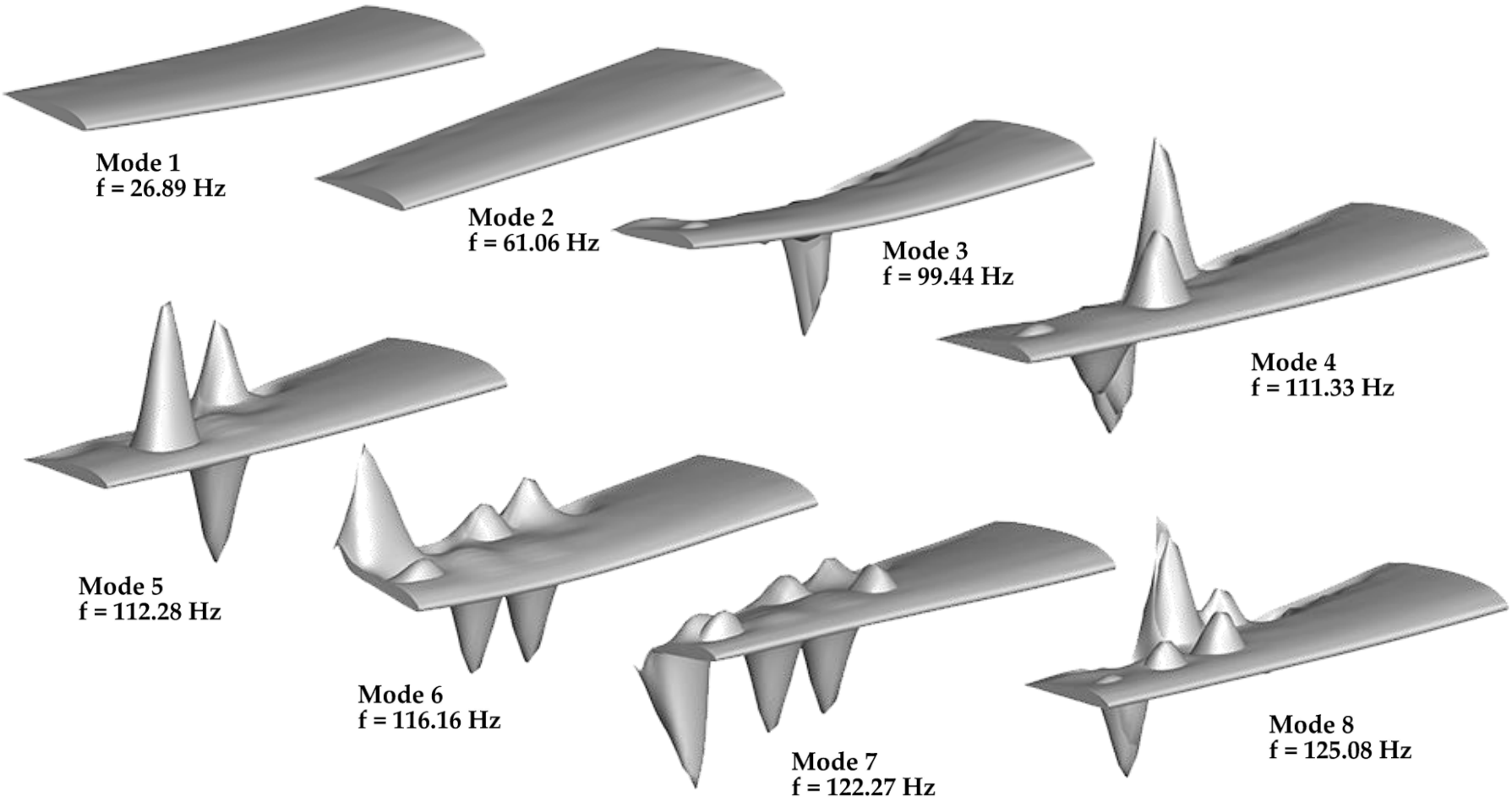
C-H structured 3.2 mill. Hexa, farfield at 50 MAC

Structural model

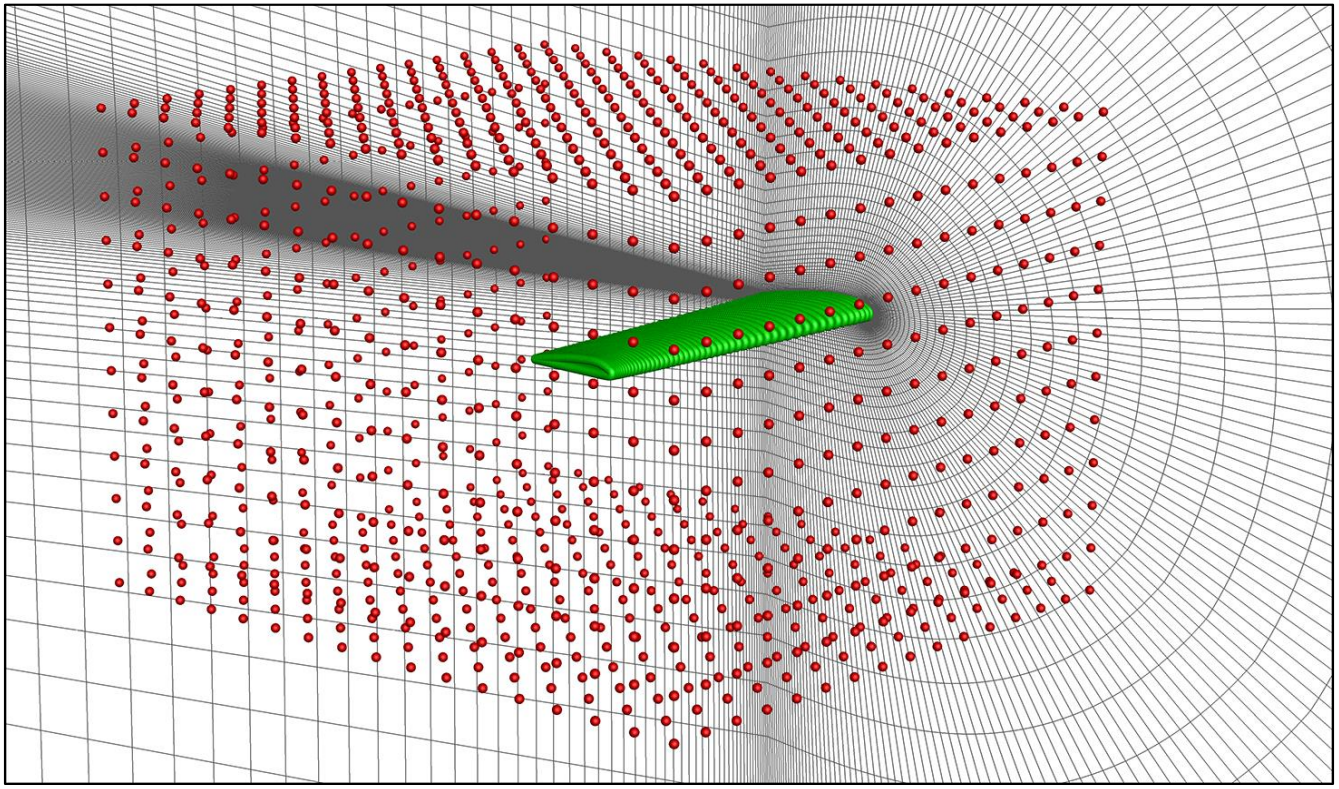


97000 shell elements

Modal shapes

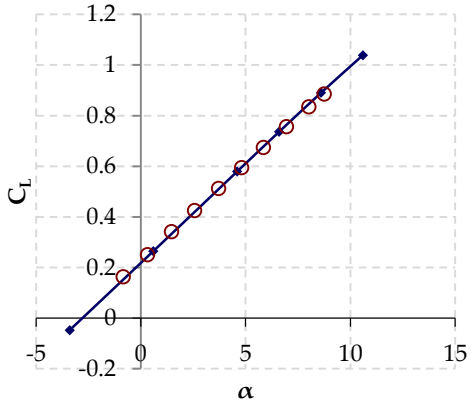


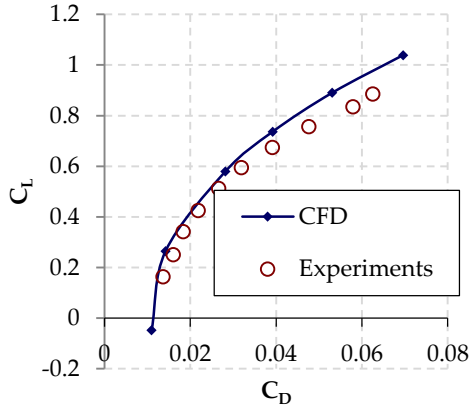
RBF problem domain

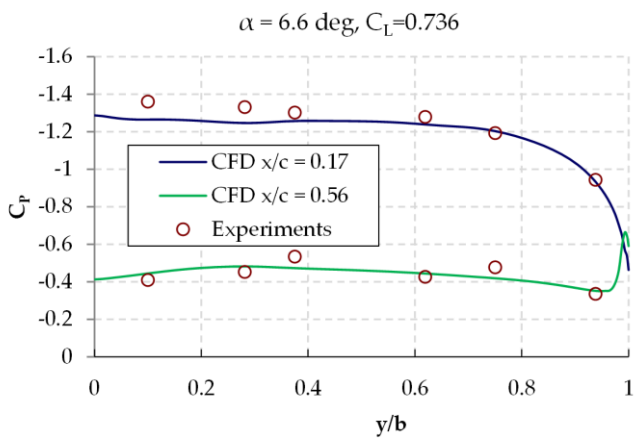


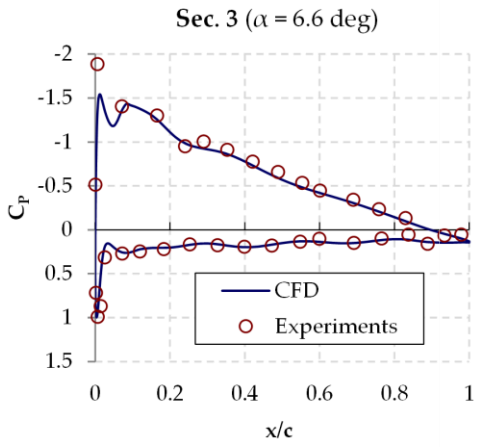
31000 source points, (fitting in 62 sec., smoothing in 40 sec.)

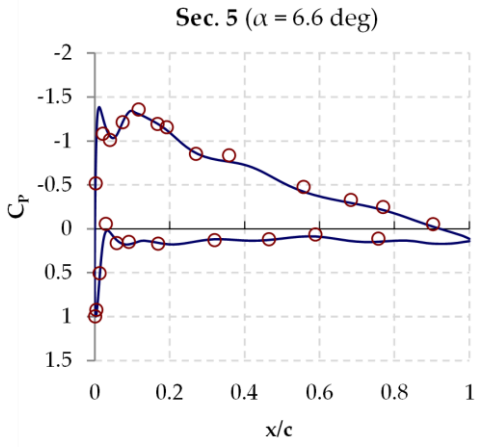
Aerodynamic solutions



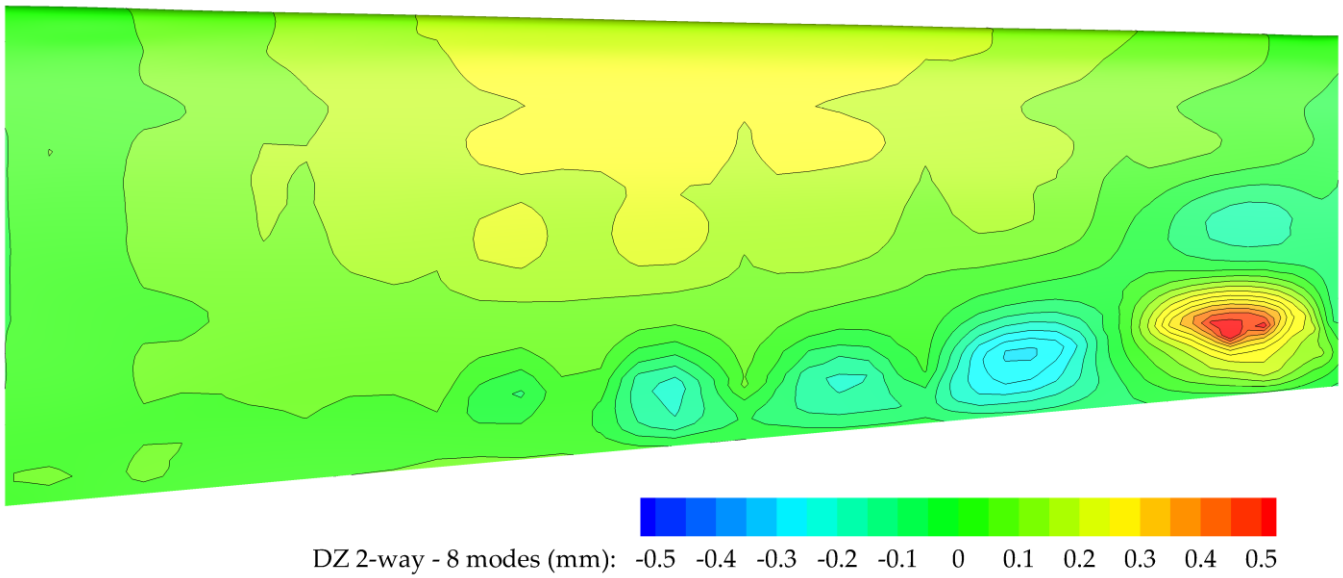






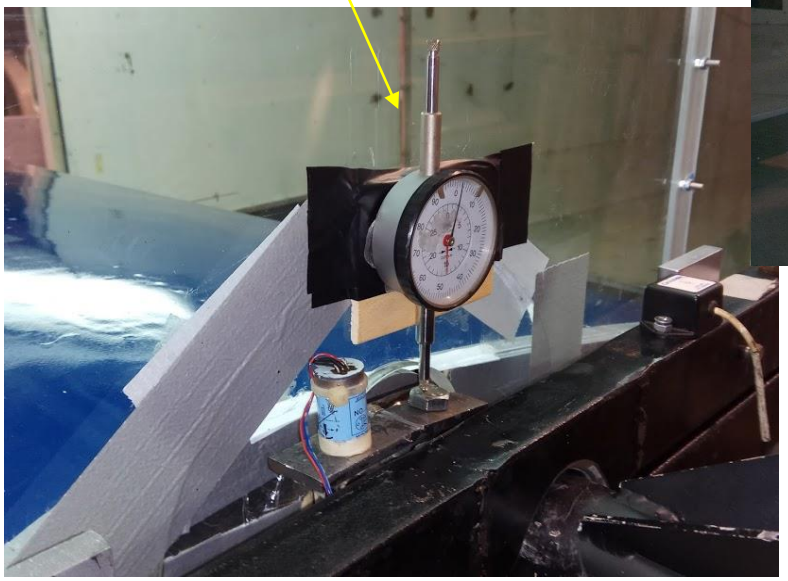


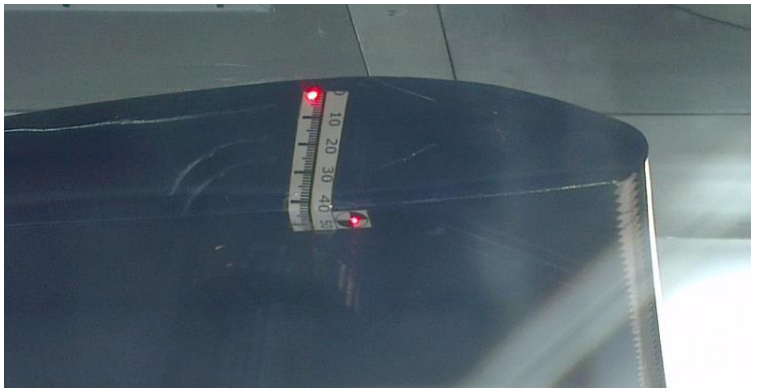
Modal base evaluation



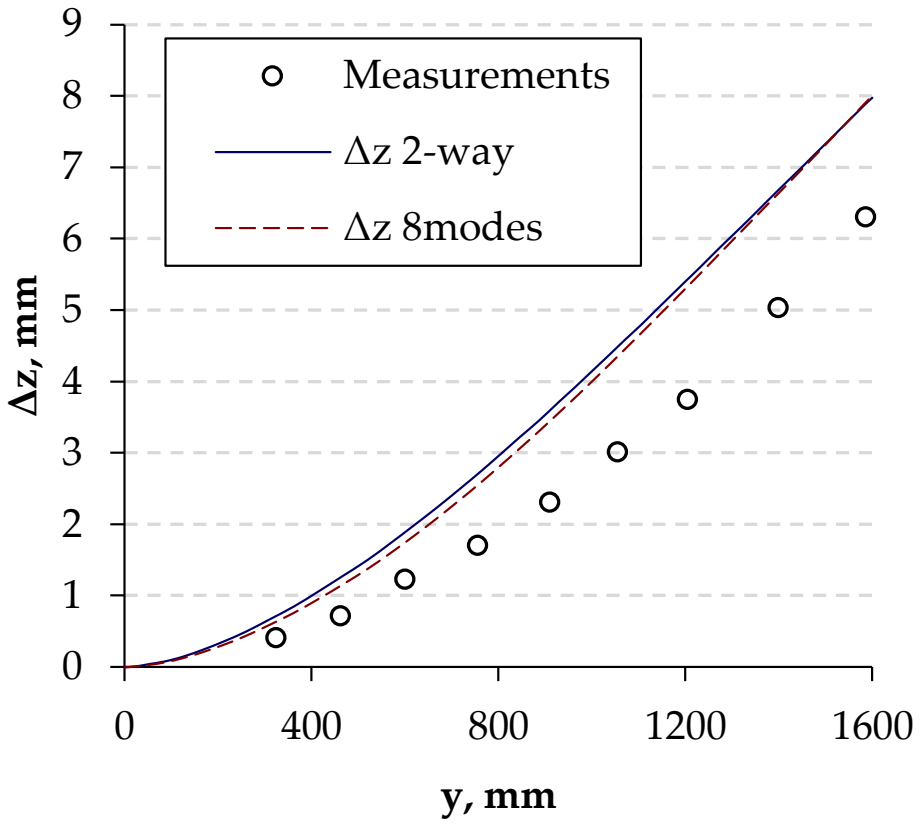
Deformation measurement

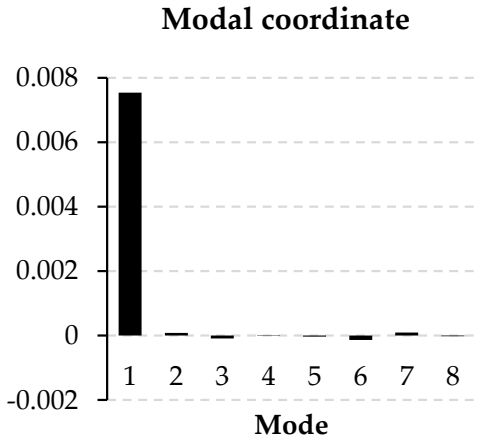
High-precision inclinometer

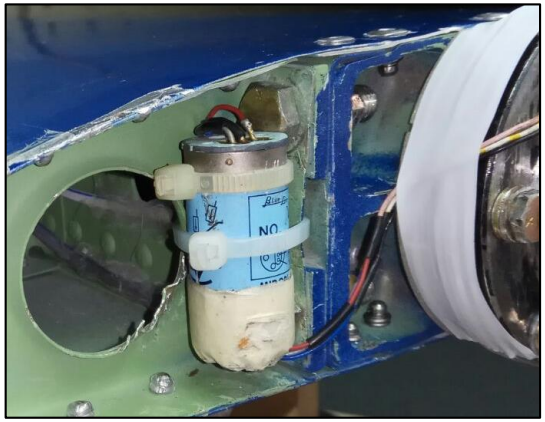




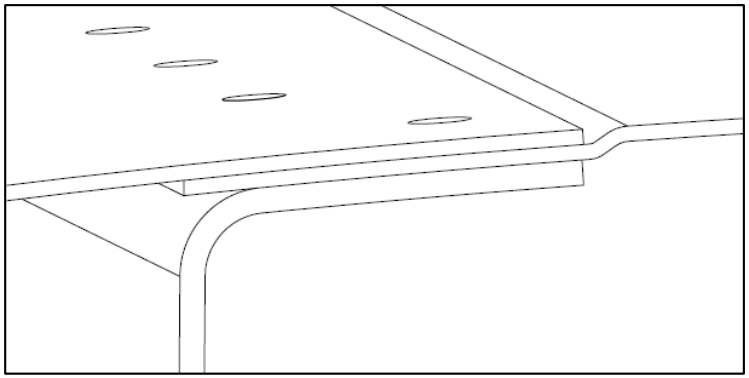
Deformation solutions

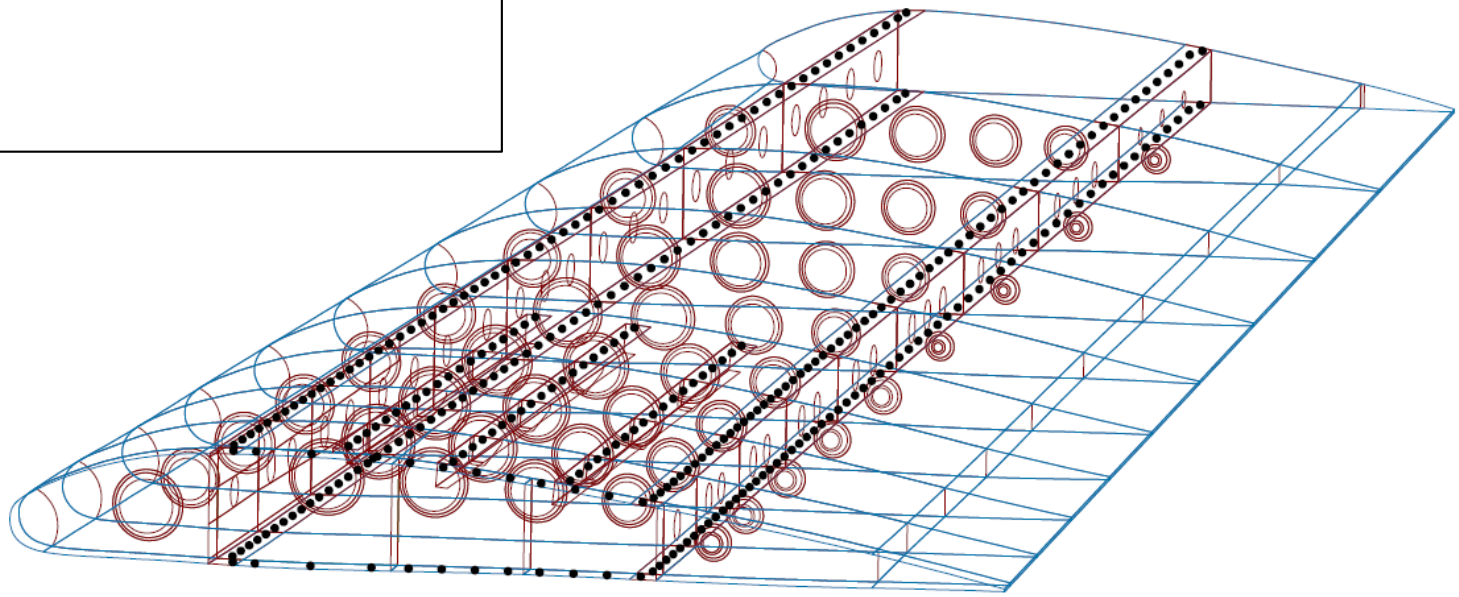






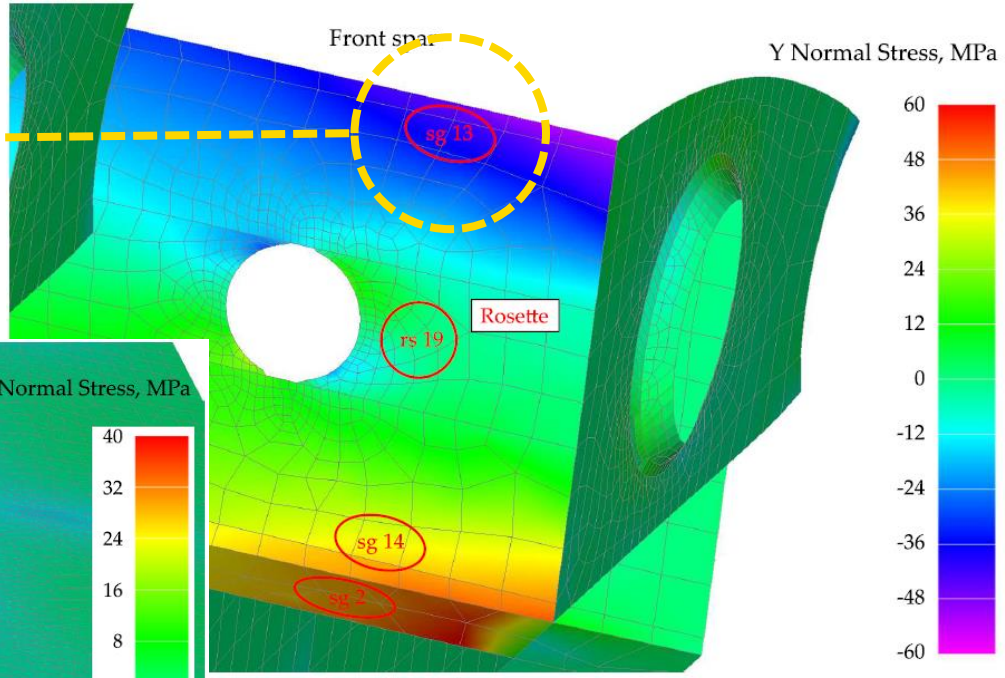
Elements junction

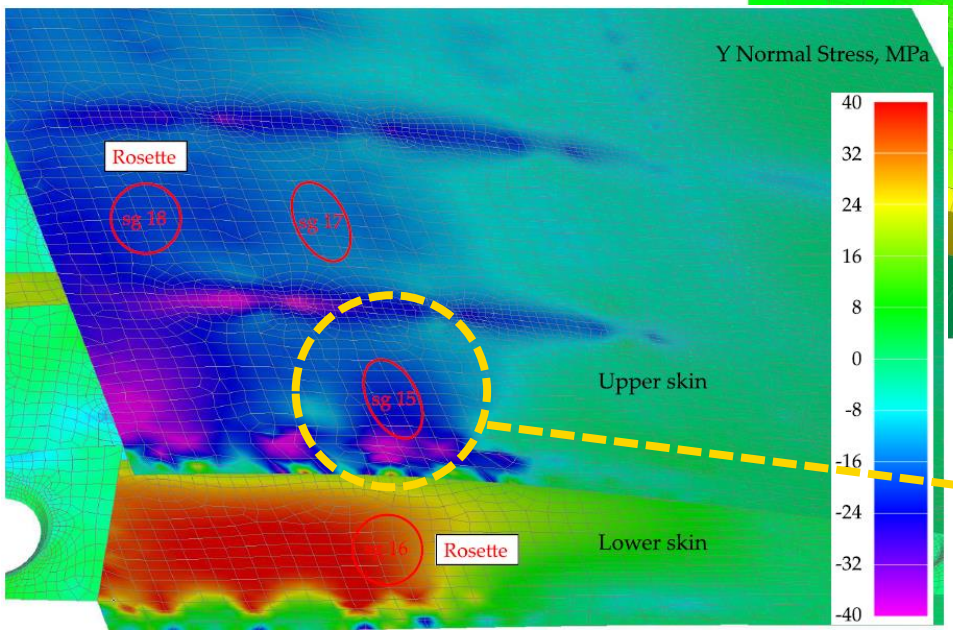




FEM verification

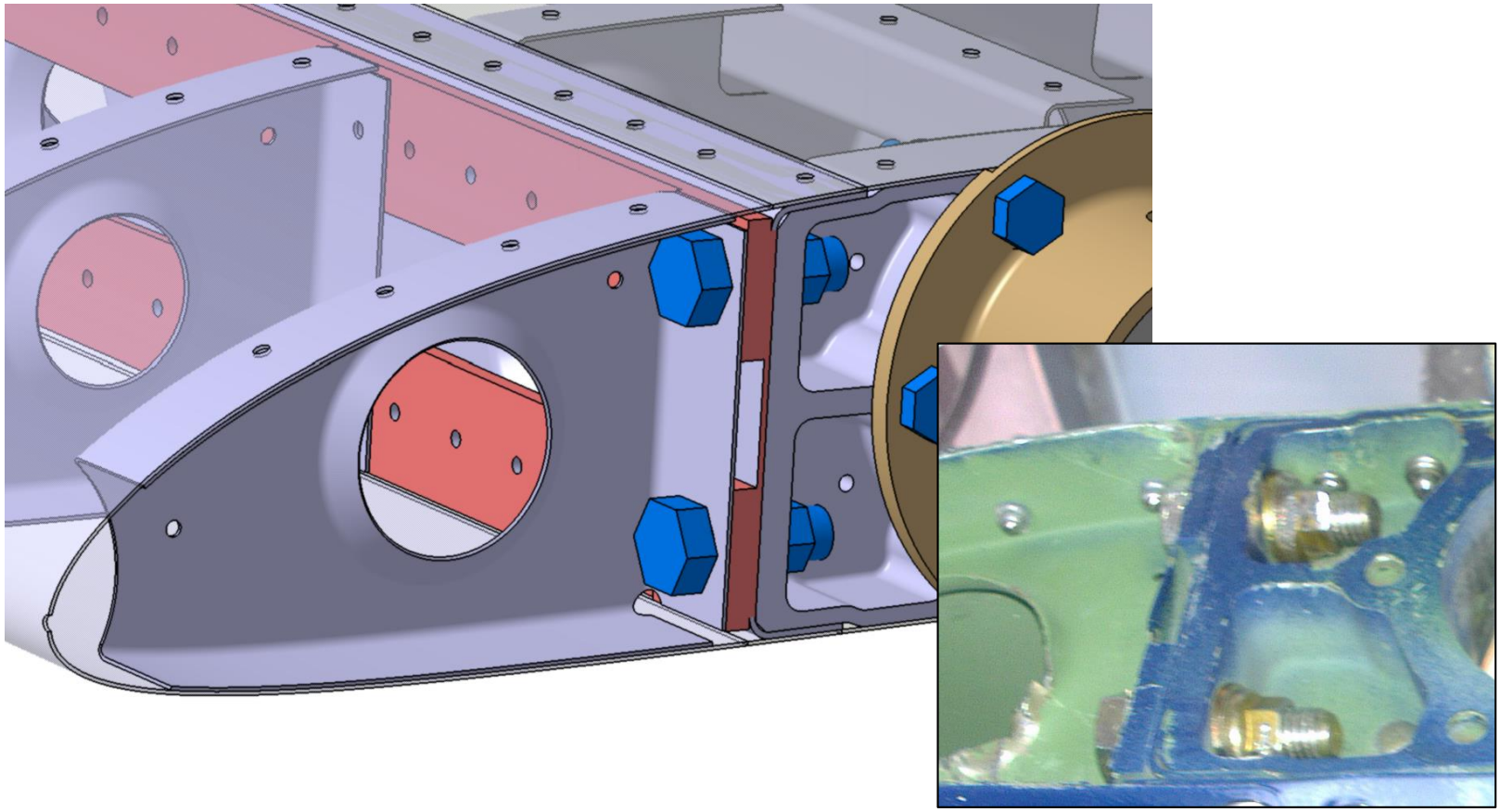
Exp. σ_y = **-15.6** *MPa*
FEM σ_y = ~ **-38** *MPa*





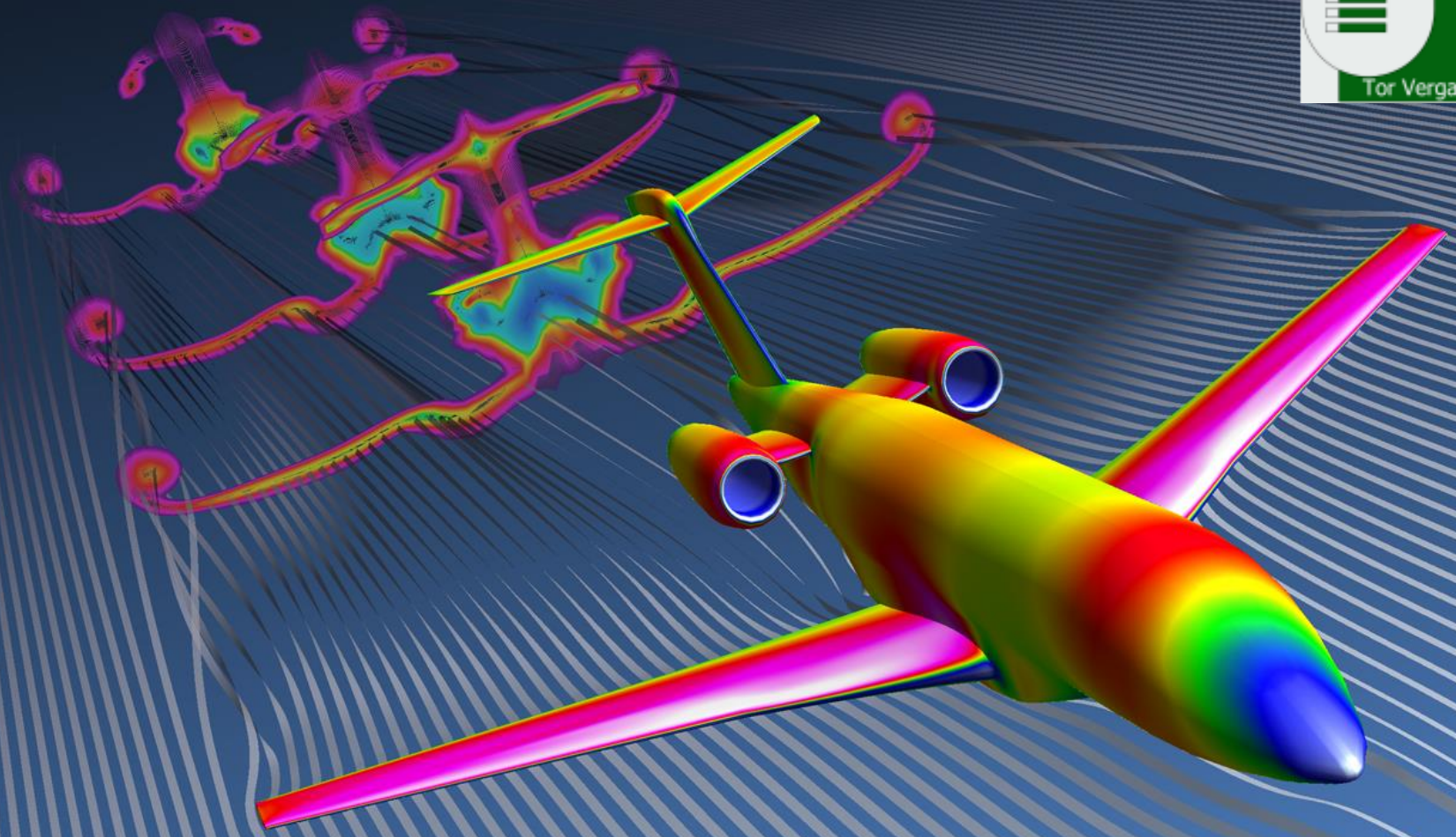
Exp. σ_y = **-143.2** *MPa*
FEM σ_y = ~ **-21** *MPa*

Spar reinforcements



Conclusions

- RBF morphing provide a very efficient and robust coupling of CFD and FEM solutions
- 2-way and modal FSI analyses provided almost the same solutions
  - the modal approach is a valid candidate to setup efficient and accurate FSI analyses of wings
  - A very poorly populated modal base us sufficient for lifting surfaces
- Failure in modeling the load shared between skin and spar.
  - A more accurate FEM model is probably necessary for complex topologies including root junctions



Thank you for your attention

Ubaldo Cella