Finanziato dall'Unione europea NextGenerationEU | Ministero dell'Università e della Ricerca | Italiadomani PIANO NAZIONALE DI RIPRESA E RESILIENZA | ROME TECHNOPOLE INNOVATION ECOSYSTEM

ECS 0000034 – Rome Technopole

Spoke 2 – Technology transfer, new entrepreneurship, business incubation and acceleration

TECH TRANSFER DAY

Industrial impacts of technology transfer in the Rome Technopole
University of Rome Tor Vergata - 14/11/2024

Project Title

DigiPAD - Digital Twin for Advanced Design in the Aerospace Industry

Principal Investigator

Ubaldo Cella – RBF Morph

Partners

RBF Morph - SmartUp Engineering

PROJECT OBJECTIVES

- The project aims to combine two proprietary technologies (JPAD owned by SmartUp Engineering s.r.l. and RBF Morph owned by RBF Morph s.r.l.), to create a numerical tool able to significantly **enhance aircrafts design process**.
- The objective is to generate a preliminary design tool based on parametric model of aircrafts able to produce as output a **Digital Twin** generated by the compression of a database of **high-fidelity analyses** of the configuration under investigation.
- The designer will be then able to evaluate in **real time** the impact of several variables of design with an accuracy that common preliminary design tools are not able to provide.
- The capability to rise the accuracy in the preliminary phase of design will significantly **speed-up the design process** supporting the identification of more efficient (greener) aircrafts.
- The software will give the proponents the possibility to offer an **innovative service** within the market of aerospace industries.
- It is expected to reach a **Technology Readiness Level (TRL) of 7** (System prototype demonstration in operational environment) at the end of the project.

DESCRIPTION OF THE PROJECT

- **JPAD** is a preliminary design, multidisciplinary analysis, and aircraft optimization tool based on a geometric model, **RBF Morph** is a shape parameterization tool based on mesh morphing techniques, capable of making geometries and numerical analysis domains parametric.
- Within DigiPAD the link between the two technologies will be developed to create an **accurate parametric preliminary design tool**.
- The main key points of the technologies developed involve:
  - The implementation of **iso-topologies generation capability** within JPAD.
  - The implementation of a **CAD2CAD procedure** able to synchronize the geometric parametric model with the CFD numerical domain.
  - Implementation of procedures for the **generation of the CFD solutions database**.
  - The identification of **machine learning methods** and numerical **data compression** to manage the CFD database generating a Digital Twin of the parametric model.
  - Implementation within JPAD of **post processing capability** of the generated Digital Twin.
- The final output will be a **demonstrator** to be evaluated in an operative environment.

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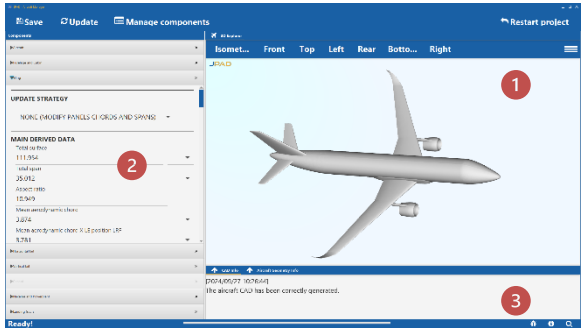
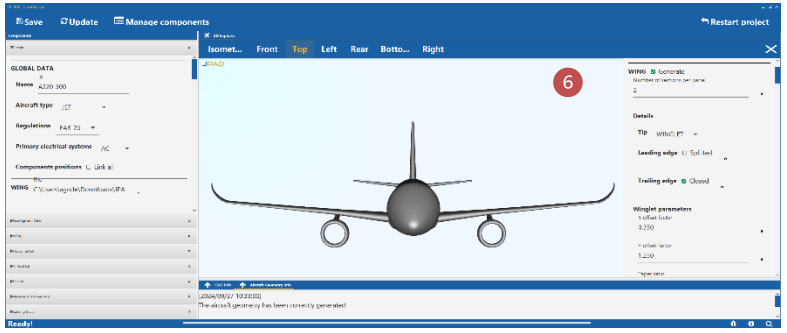
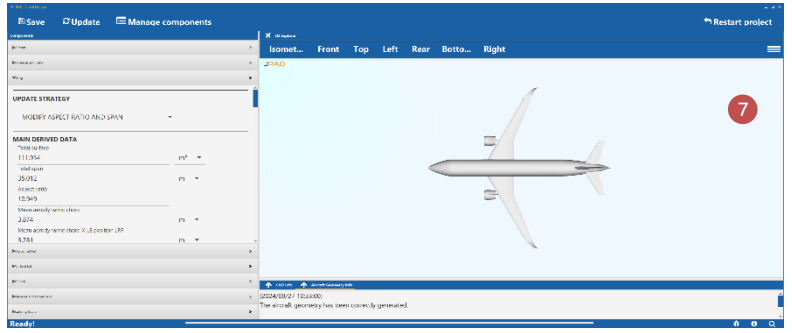
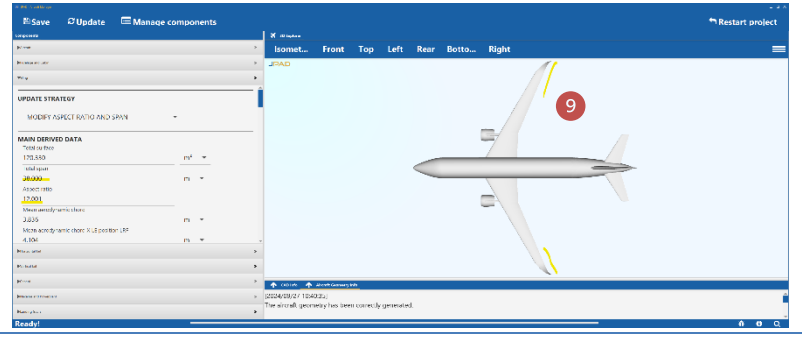
DEFINITION OF THE AIRCRAFT GEOMETRY PARAMETERIZATION

- **JPAD**: Java API (Application Programming Interface) for Aircraft Design.
- **JPAD Modeller**: Desktop app as a visual tool to edit end export aircraft configurations. 1-2-3-4
- Refined setup of CAD geometry and export formats (e.g. Brep). 4-5









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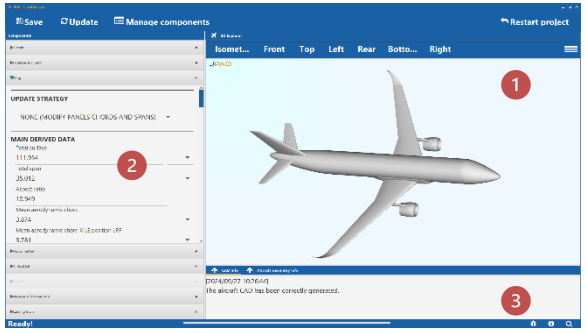
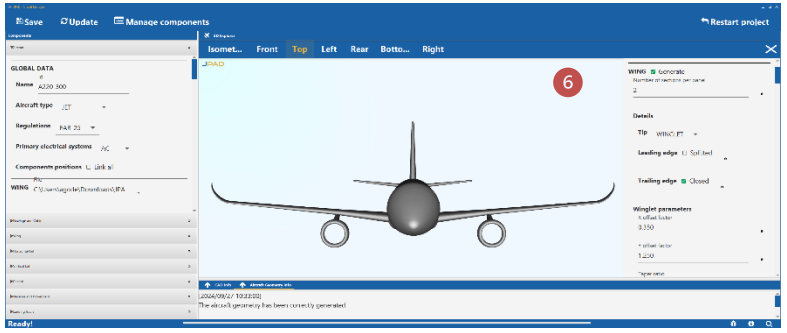
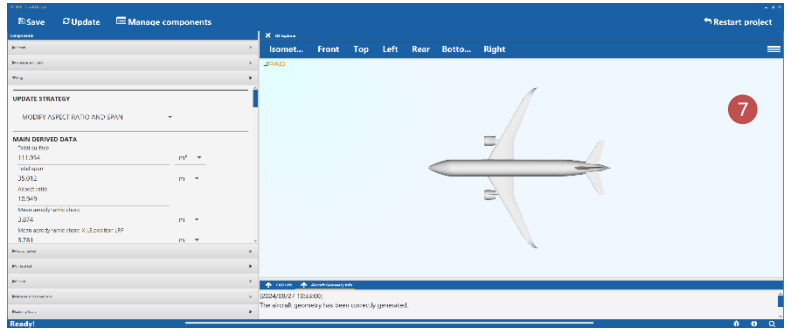
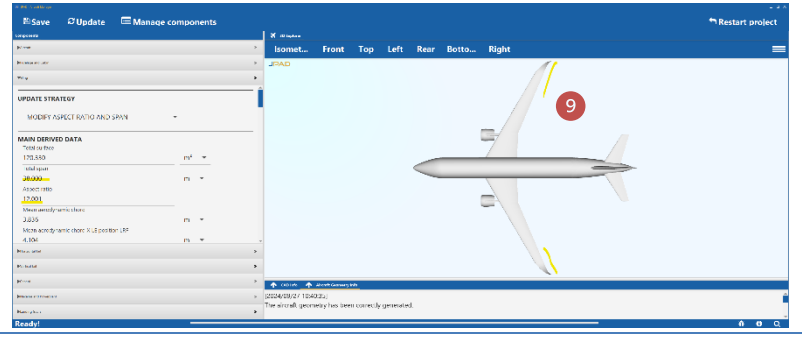
DEFINITION OF THE AIRCRAFT GEOMETRY PARAMETERIZATION

- **DigiPAD Reference model**: baseline model similar to an Airbus A220-300; includes winglets, nacelles and pylons. 6-7
- The model's parameters can be adjusted with several GUI controls. 8
- The **geometric variants** can be inspected and exported to various CAD formats, including Brep. 9









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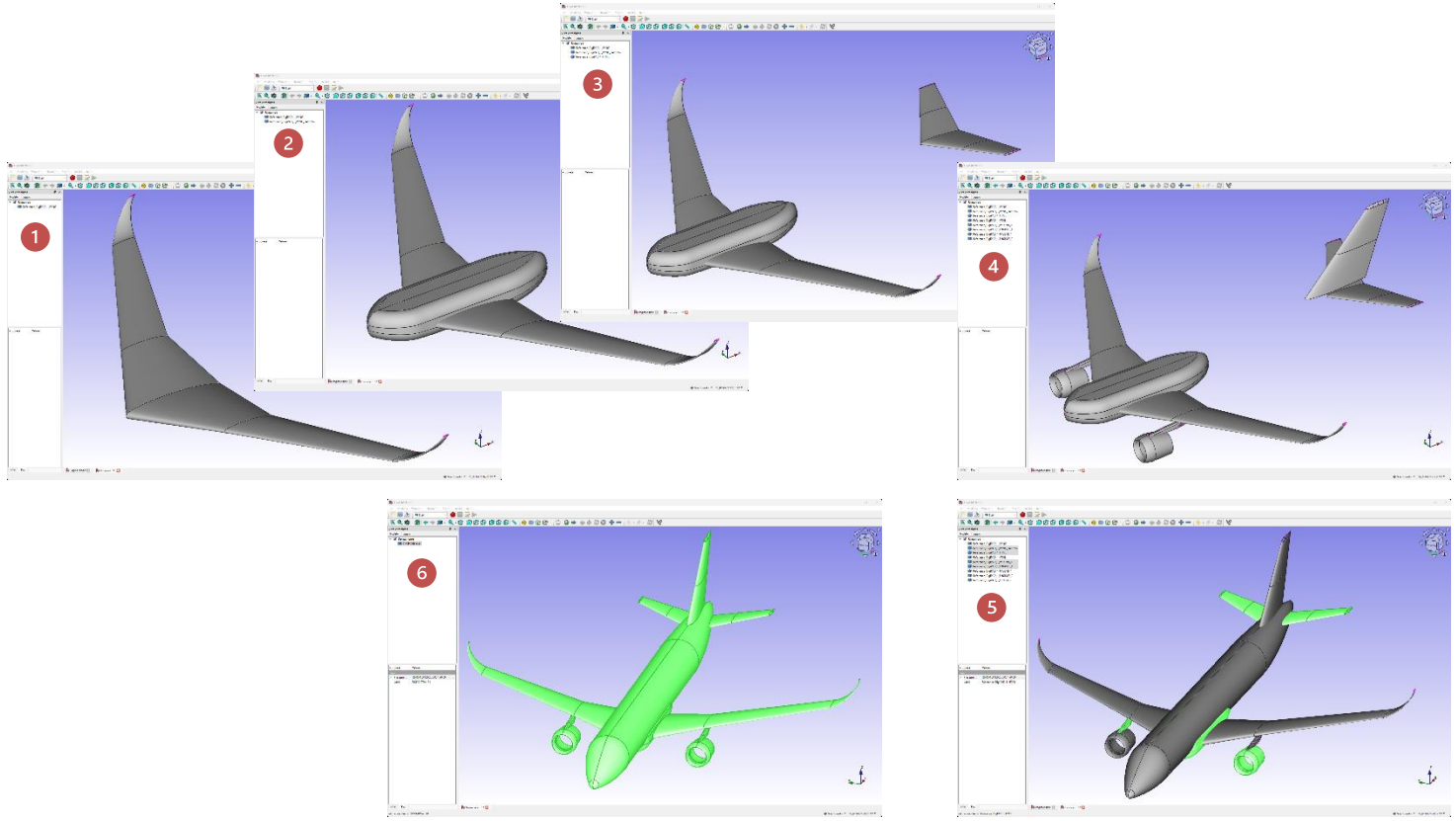
MODELING AND DATA EXCHANGE ON THE DigiPAD PLATFORM

- **BRep**: The best format to deal with when exporting from **JPAD** to **rbf-morph** is the *Boundary Representation* (BRep).
- **JPAD Modeller standard export format**: The initial - and standard - export format provides a solid representation of aircraft geometry as a collection of solids. 1-2-3-4
- The user can chose to produce separate files for each component, or a single file with all solids. 1-2-3-4-5



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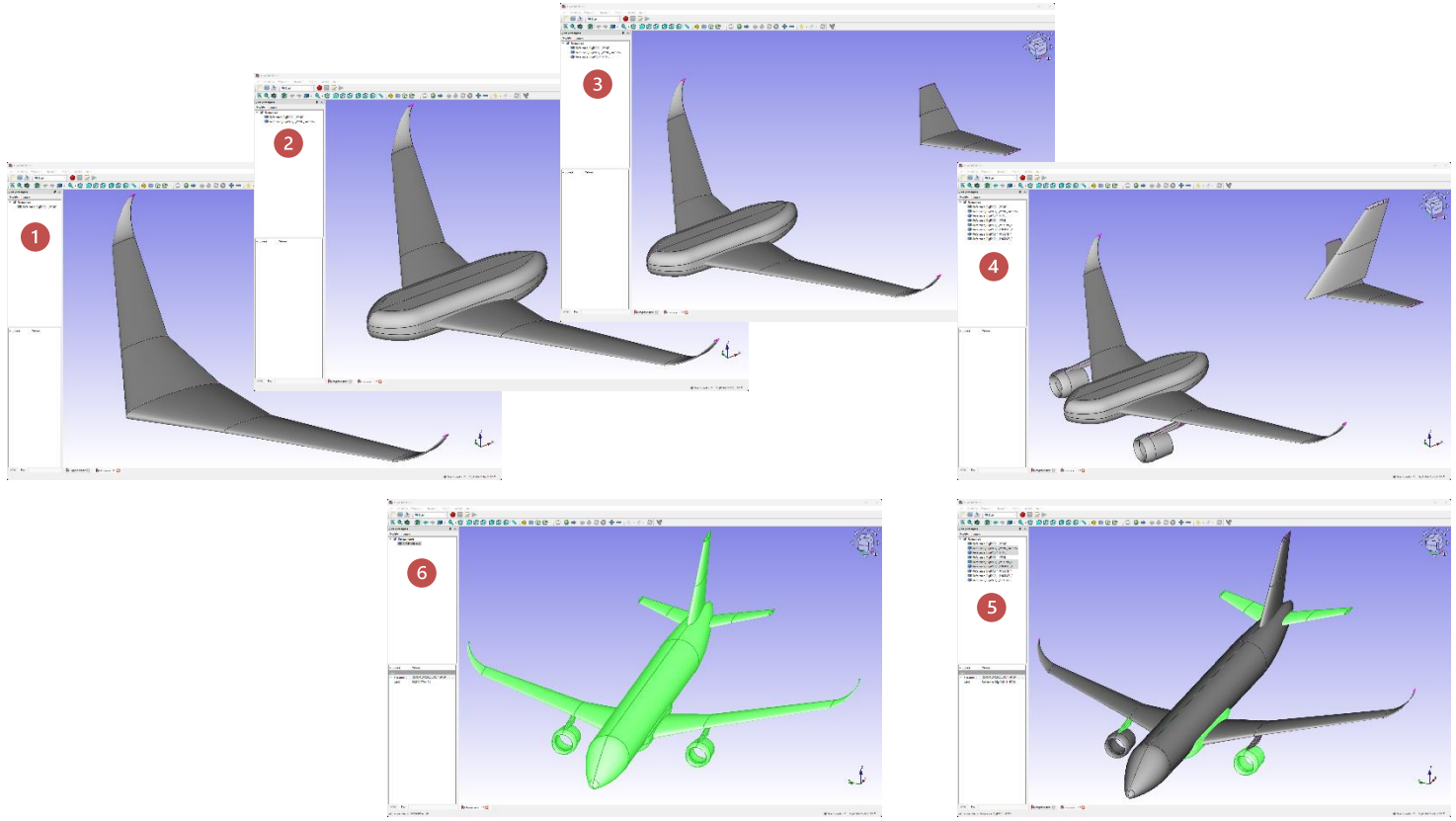
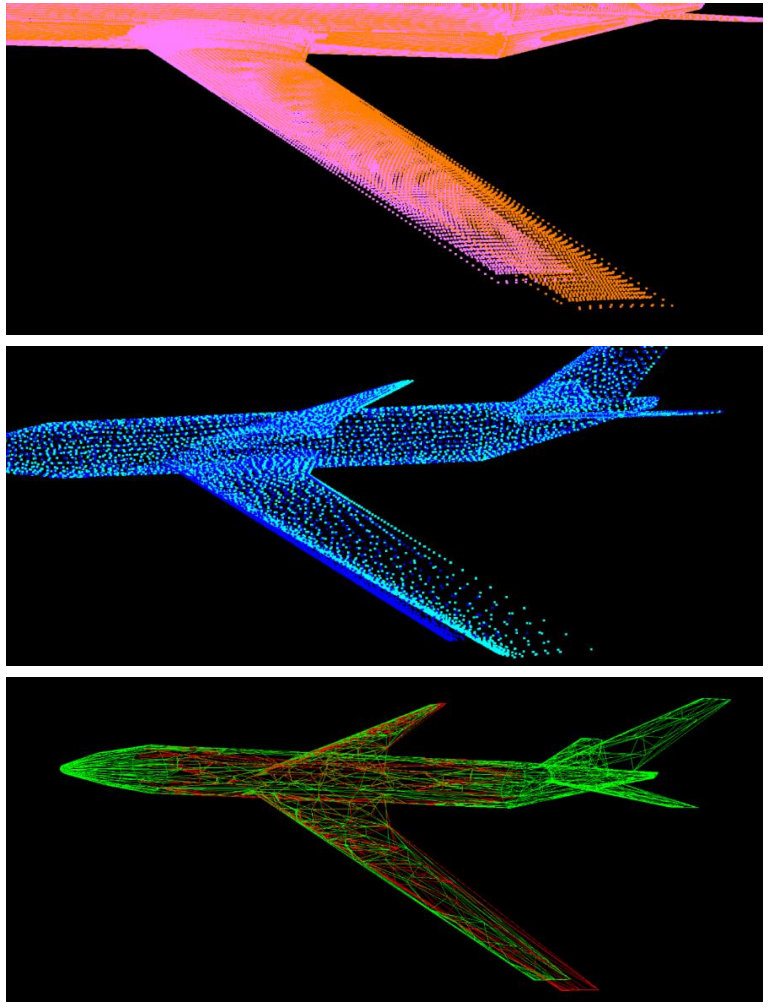
MODELING AND DATA EXCHANGE ON THE DigiPAD PLATFORM

- Refined setup of CAD geometry and export formats (e.g. Brep). 5
- **JPAD**'s low-level procedures based on **OpenCASCADE Technology (OCCT)** have been adapted to produce a *union* of all components in a configuration.
- The exported CAD now includes a single united solid with all necessary subsurfaces and intersection curves handled by **rbf-morph**. 6
- This feature ensures that all variants produced by JPAD are iso-topologic.



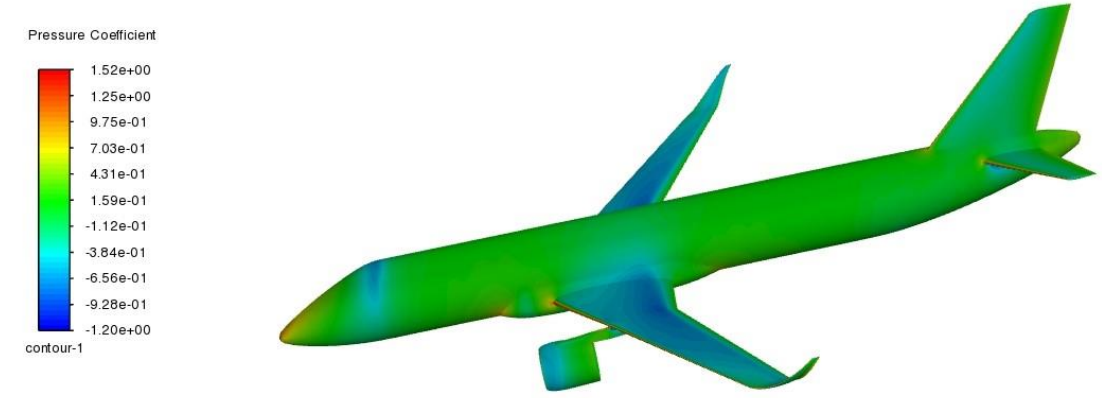
RBF CAD2CAD MODULE DEVELOPMENT

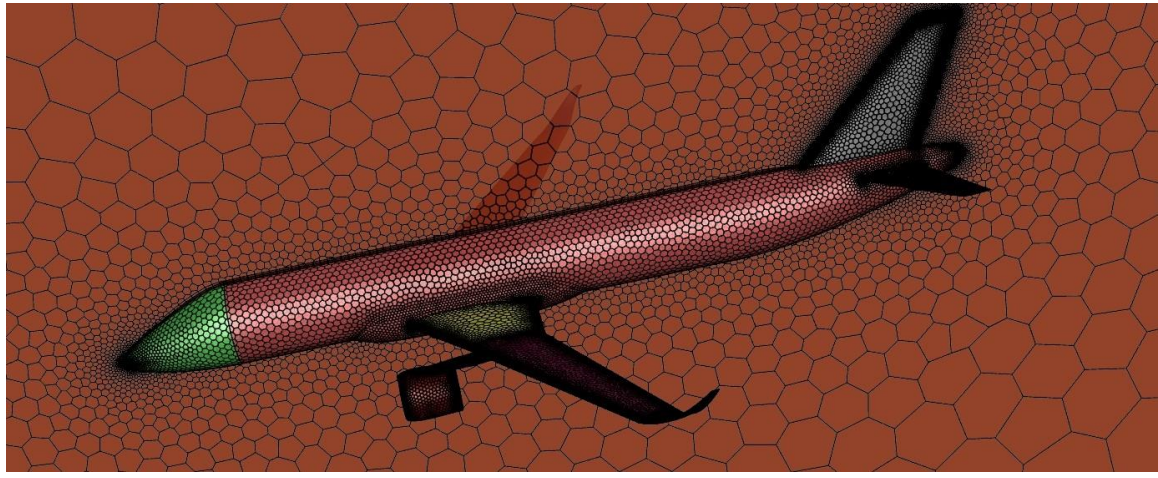
- Development of a **tool to generate point clouds on a reference CAD geometry and corresponding** variants.
- Challenges: Identify homologous surfaces and edges. Preserve original CAD geometric constraints. Ensure **iso-topological** consistency (same number of edges, surfaces, and curves across CADs).
- **ROC executable:** Operates in stand-alone mode. Starts from a series of CADs (baseline + modified). Automatically generates meshes for each new CAD. Recognizes geometry topology in CAD variants. Uses Radial Basis Functions (RBFs) to create consistent meshes.
- Libraries: **RBF Morph** for mesh deformation. **OpenCASCADE** for CAD geometry processing.



GENERATION OF HIGH-FIDELITY CFD ANALYSIS CONFIGURATION

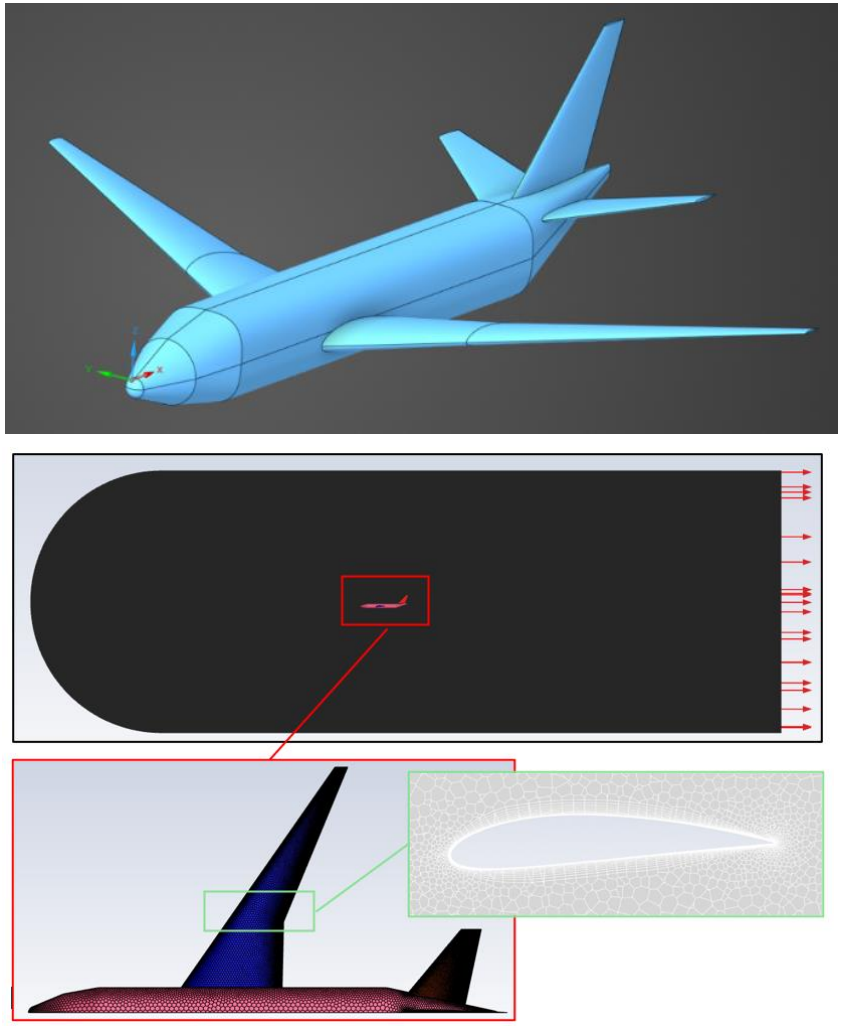
- **Mesh information**:
  - Mesh with 5mil polyhedral volumes
  - Surface Mesh: Min size 0.0005 m on the wing trailing edge
  - Boundary layer 3 on the wall with smooth-transition method type
  - Volume mesh: Polyhedral elements with Max cell length 15 m
- **Boundary conditions**:
  - Velocity inlet, pressure outlet, far field, symmetry and wall
  - M = 0.75 cruising speed
  - The simulation ran 2000 steps, The convergence is obtained for the turbulence and velocity at 0.001, energy at 1e-6, for continuity the residuals are around 0.0013.





OPAM: VR DESIGN DASHBOARD

- A **CAD modeler** is directly **linked** to **CFD simulation** results
- The **OPAM** (Open Parametric Aircraft Model), a simplified model of the Boeing 787, is considered as a case study
- **CAD parameterization** and **mesh morphing** are combined to generate the design points
- Reduced Order Models (**ROMs**) are developed to link the results of CFD analyses to the chosen parameterization
- The ROMs are exported as **FMUs** (Functional Mockup Units)
- Finally, a **VR design dashboard** is created in Unity environment enabling the interaction with the geometric model



OPAM: VR DESIGN DASHBOARD

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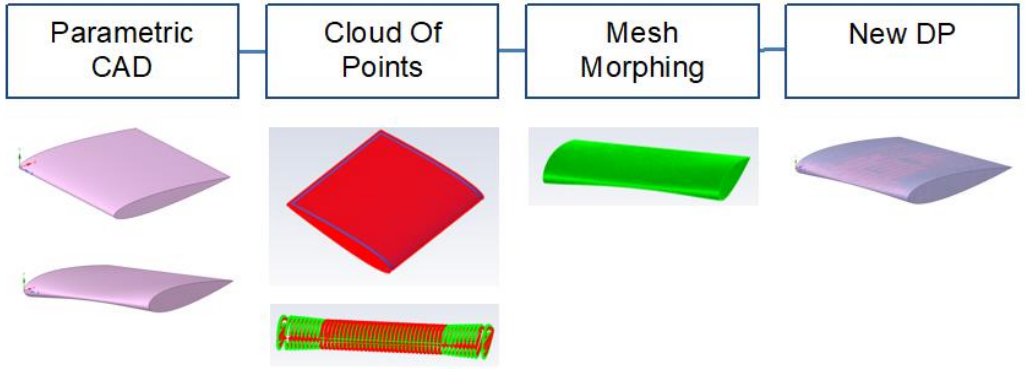
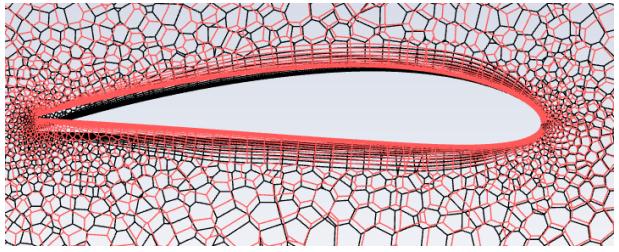
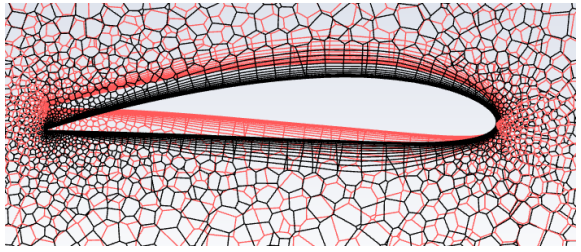
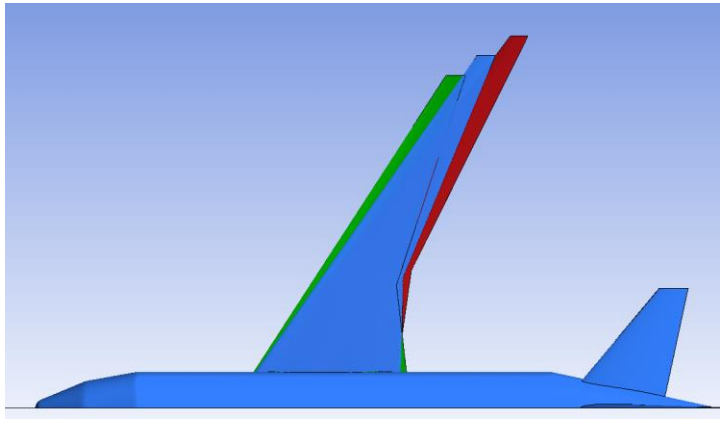


- 6 shape parameters are defined and 66 DP are created







OPAM: VR DESIGN DASHBOARD

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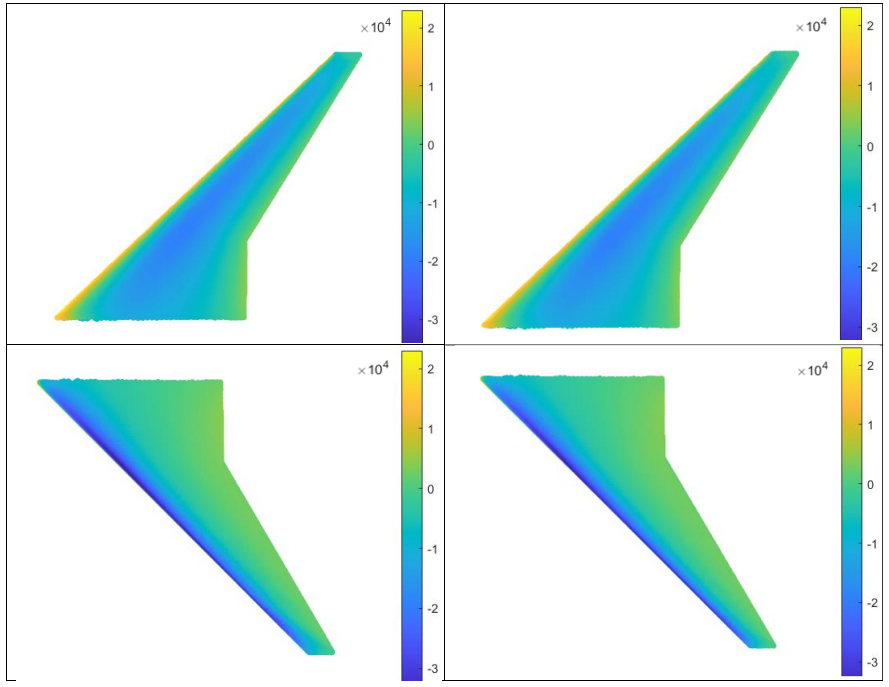
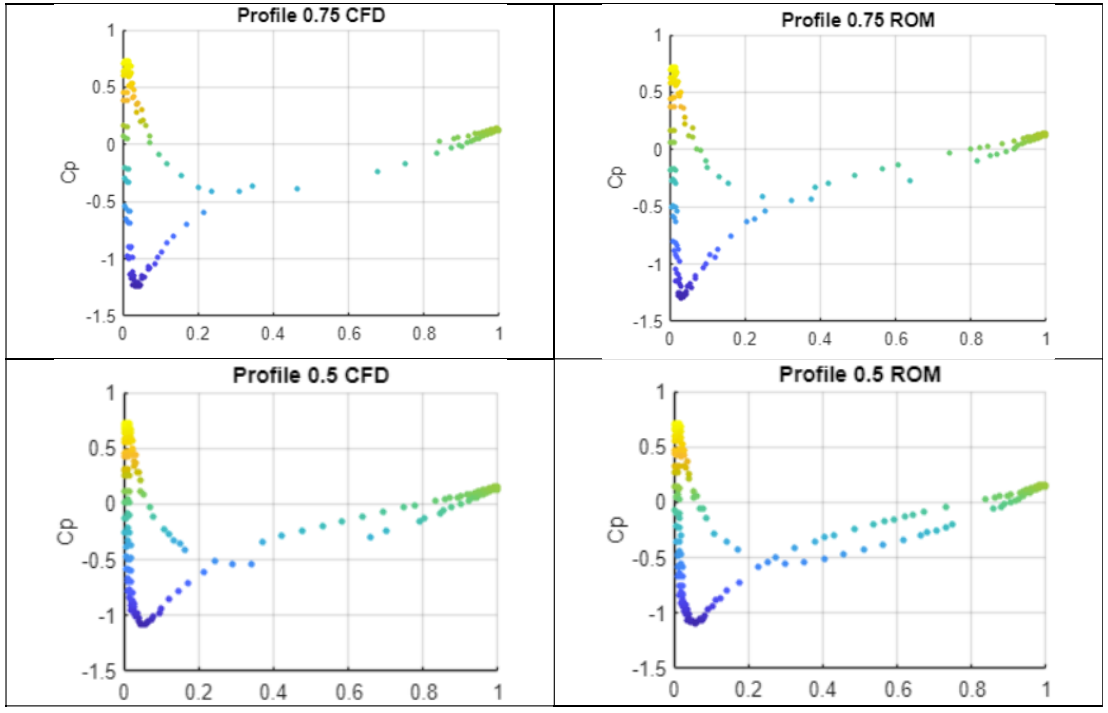


Comparison of pressure contours: CFD (left) vs ROM (right) for the DP with maximum error in the test set.



CP profile on the chord at 0.75 and 0.5, comparison between CFD and ROM for the DP in the test set with maximum error

OPAM: VR DESIGN DASHBOARD

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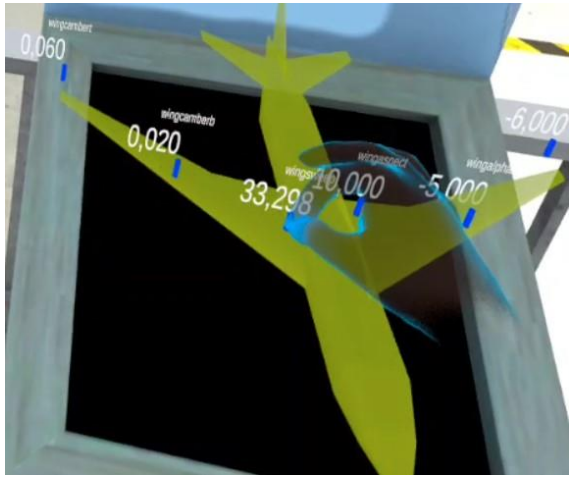

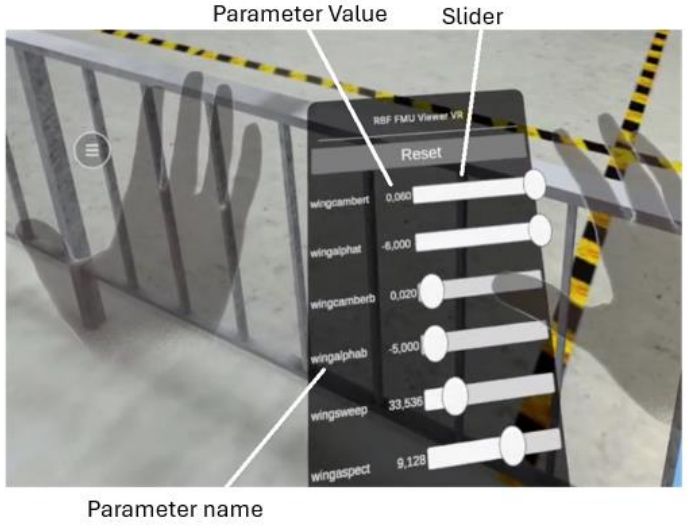

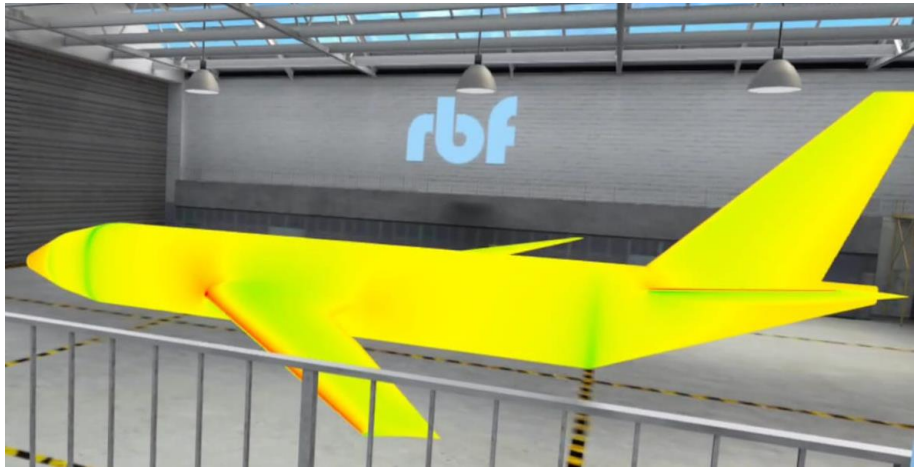

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