An efficient Digital Twin demonstrator of air intake based on machine learning and mesh morphing

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Summary:

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- Optimization workflow
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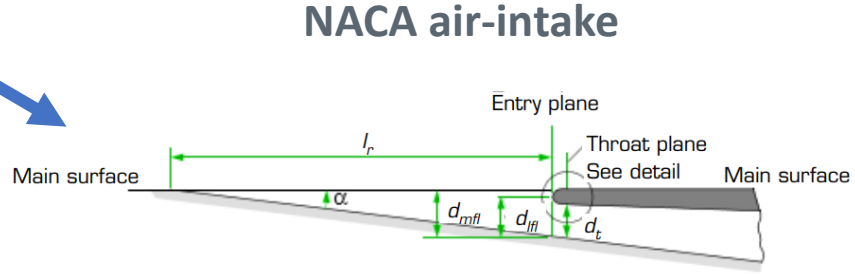
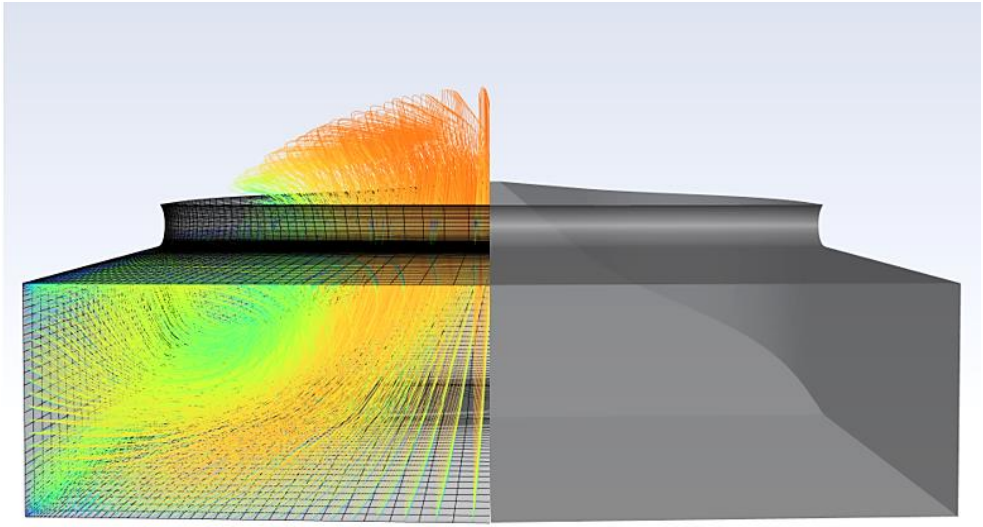
- Conclusions



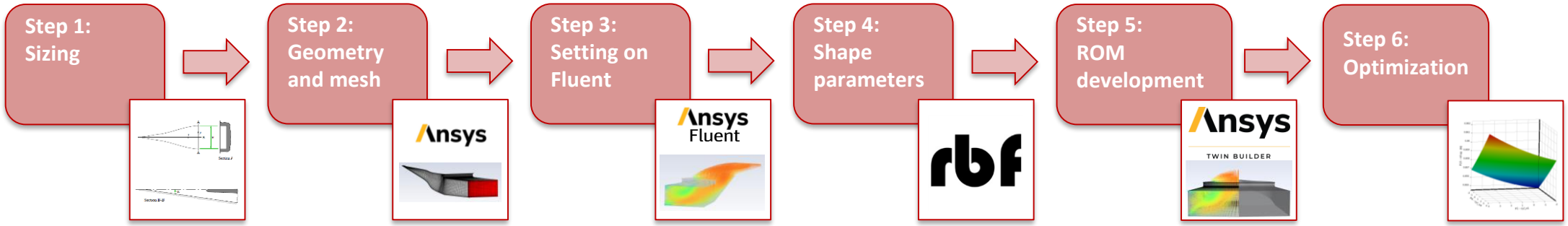
Problem definition

- This activity is focused on the generation of a **digital twin** from **numerical simulations** and **high fidelity** models of a Naca air intake;
- The aim is to create an accurate and reliable model that allows to evaluate in **real time** both scalar quantities and **field quantities**, such as the distribution of speed or pressure in the domain of interest;
- The generated model can be **integrated** with the rest of the aircraft or can be linked to an **optimization** algorithm;
- In this study the focus is on the **optimization** of the air intake.



Optimization workflow

- Step 1: Sizing, automatic script for preliminary design
- Step 2: Geometry and mesh for CFD analysis
- Step 3: Setting of CFD analysis used as snapshots for the ROM creation
- Step 4: Definition of shape parameters
- Step 5: ROM development
- Step 6: Optimization and validation of optimized shape



Sizing

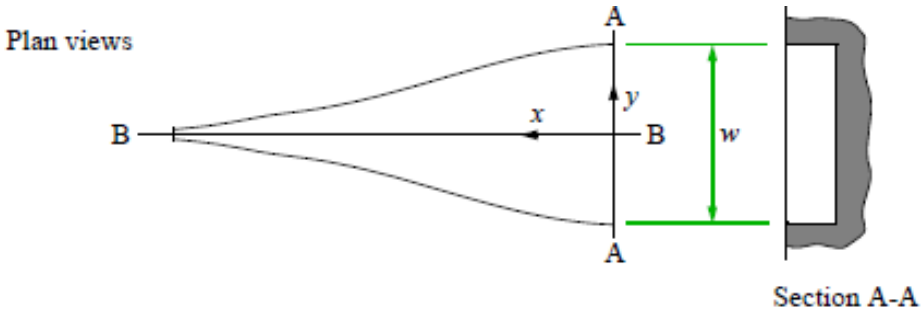
- The standard **ESDU 86002** has been used for a preliminary design
- An **automatic script** allows to size the NACA air intake:

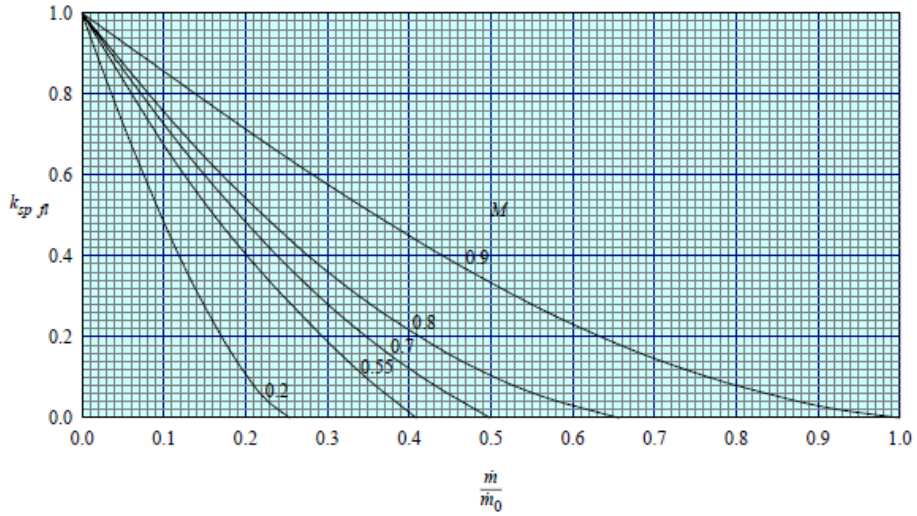
  Input:

  - Required massflow
  - Momentum thickness
  - Boundary layer thickness
  - Mach number

  Output:

  - Sizing
  - Cd
  - η

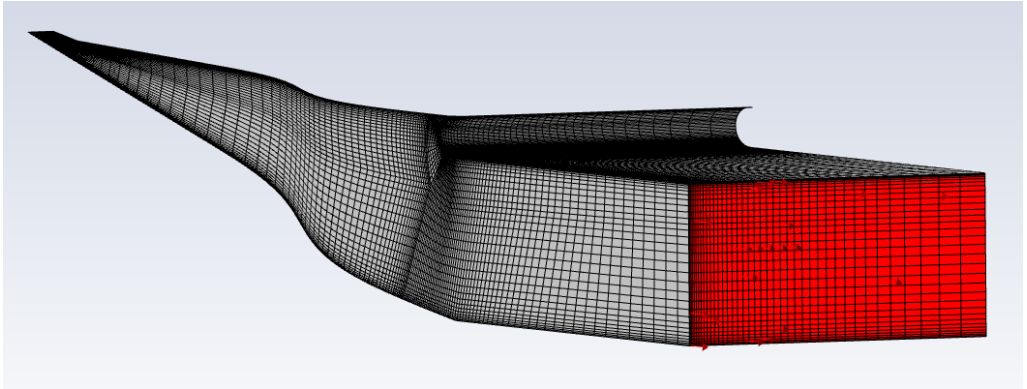


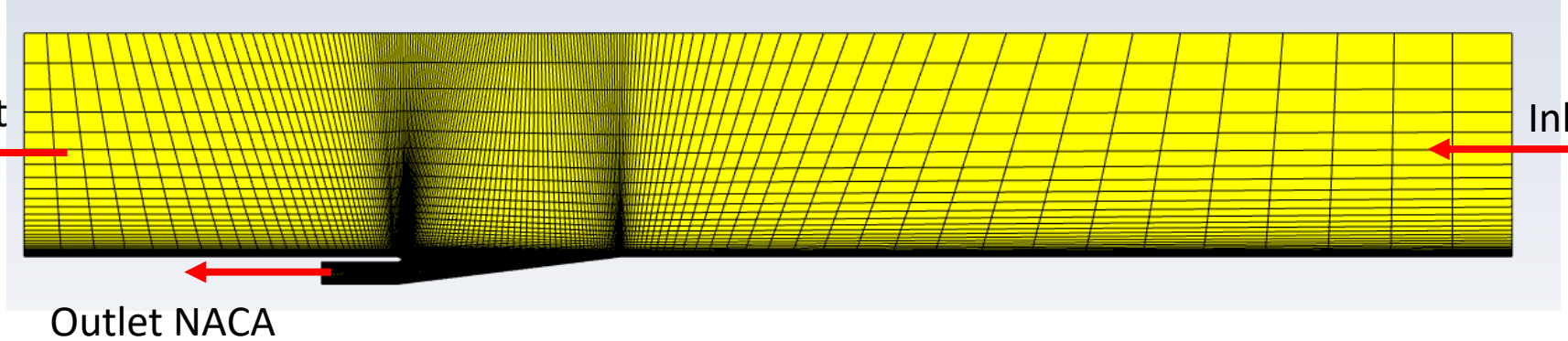


Geometry and mesh

- Structered mesh is used for a more accurate result
- Mesh statistics:

Facets	1877680
Nodes	644341
Cells	616832

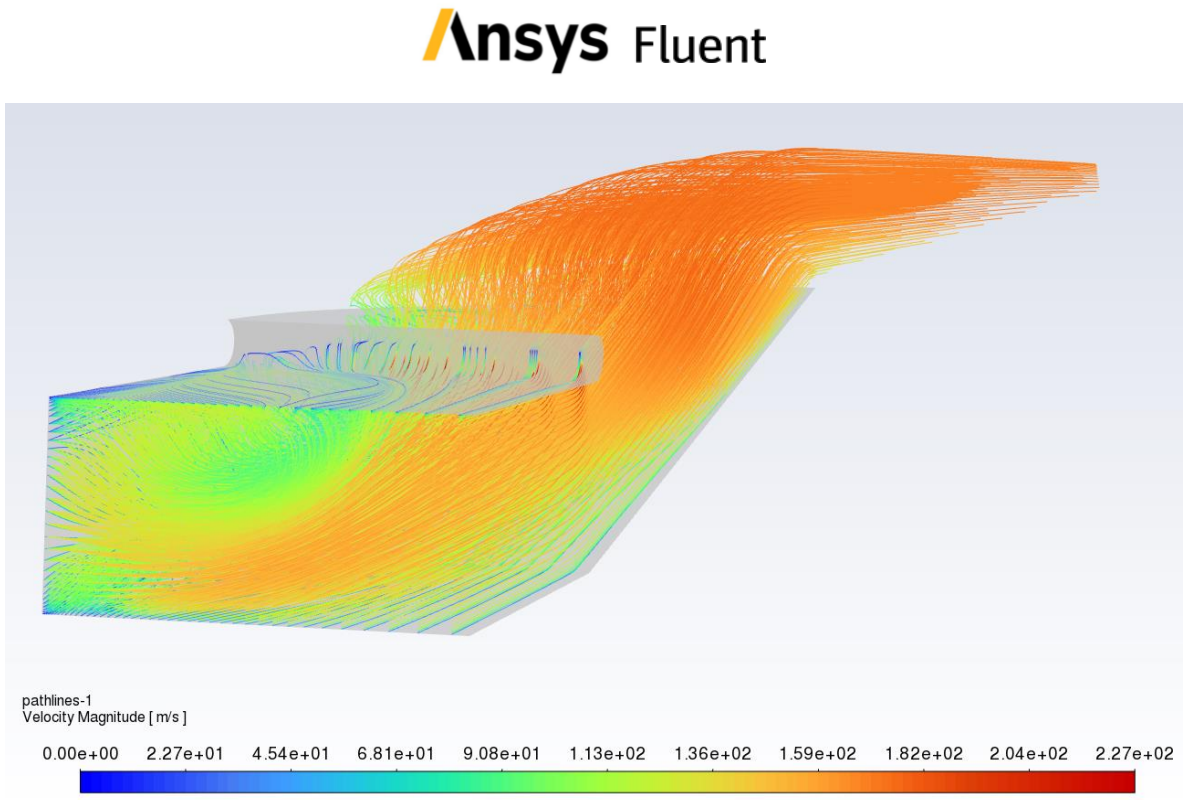




Setting on Fluent

Data:

- Required massflow : 0.23 kg/s
- Altitude 7620 m – delta ISA 20
- Pressure : 41770 Pa
- Density : 0.505 kg/m3
- Velocity inlet: Input parameter 150÷180 m/s (baseline 167.2 m/s)
- Turbolence Model: SST



Shape parameters

- **Mesh morphing** allows to define shape parameters keeping the topology unchanged
- **RBF Morph** is used as mesh morphing tool
- **8 shape parameters** are defined:

Cyl_o1

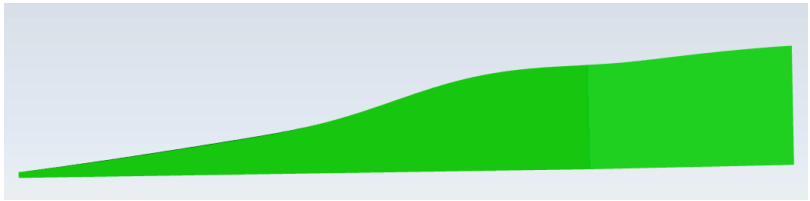
Cyl_o2

Cyl_o3

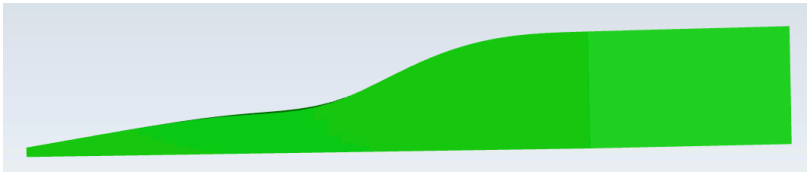
Cyl_o4

Cyl_o5

Length



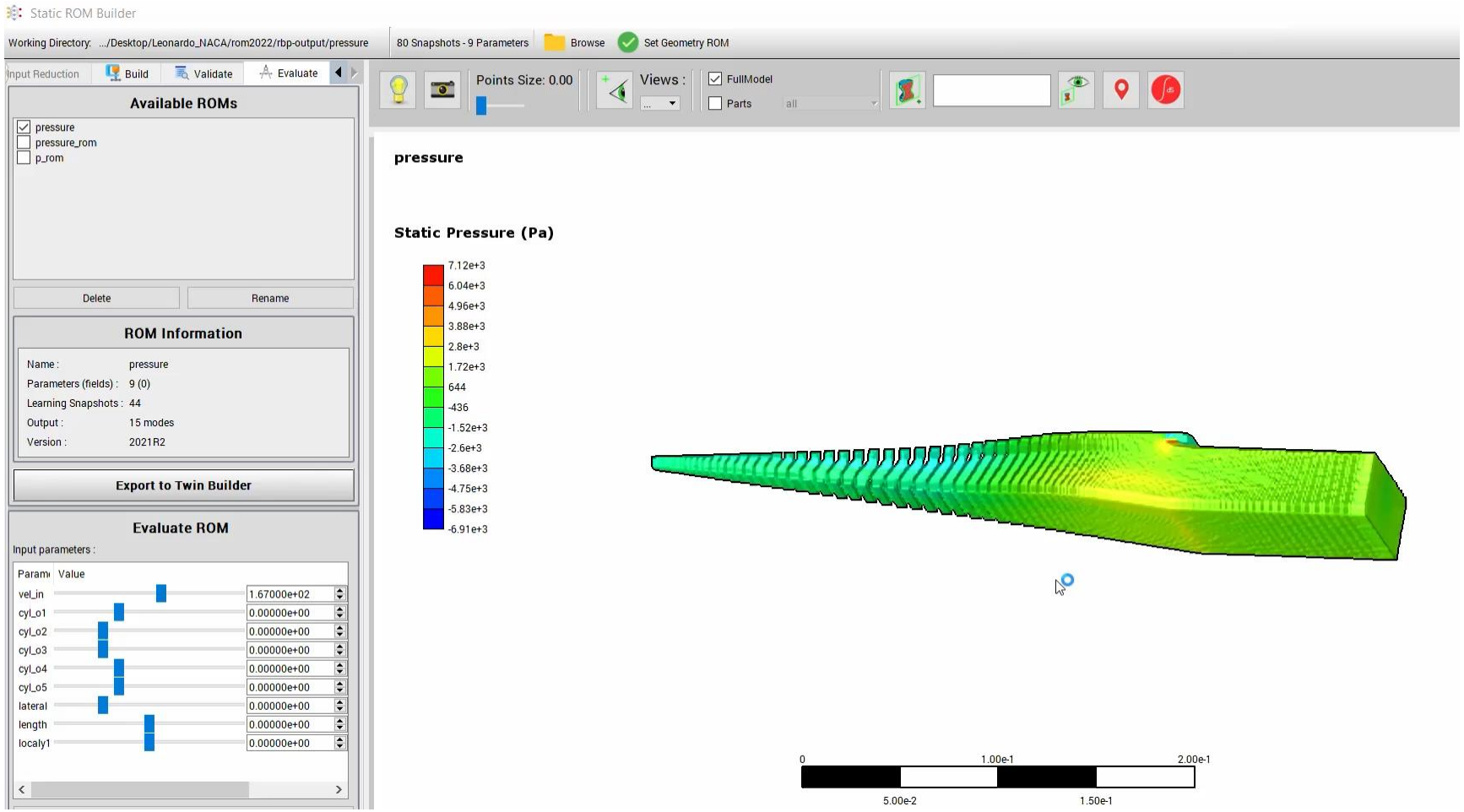
Lateral



Localy1

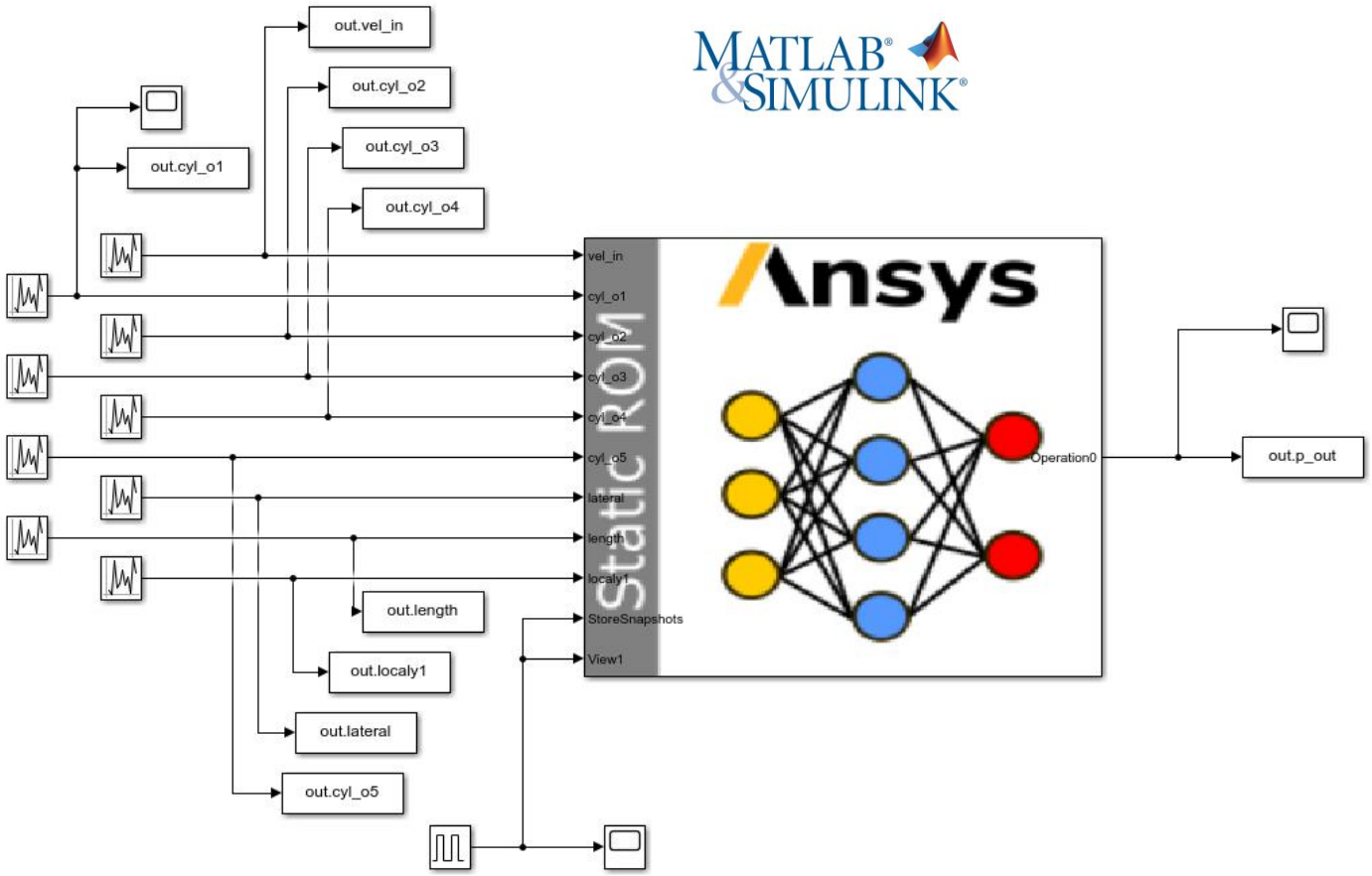
ROM: Development

- **Snapshots** collection (80 DPs)
- **Static ROM** is created using Ansys Twin Builder:
  - Decomposition algorithms (**POD**) are used to reduce the number of variables
  - **Machine learning** allows to correlate each set of input parameters to the output quantities
  - It allows to evaluate in **real time** both field quantities and scalar outputs



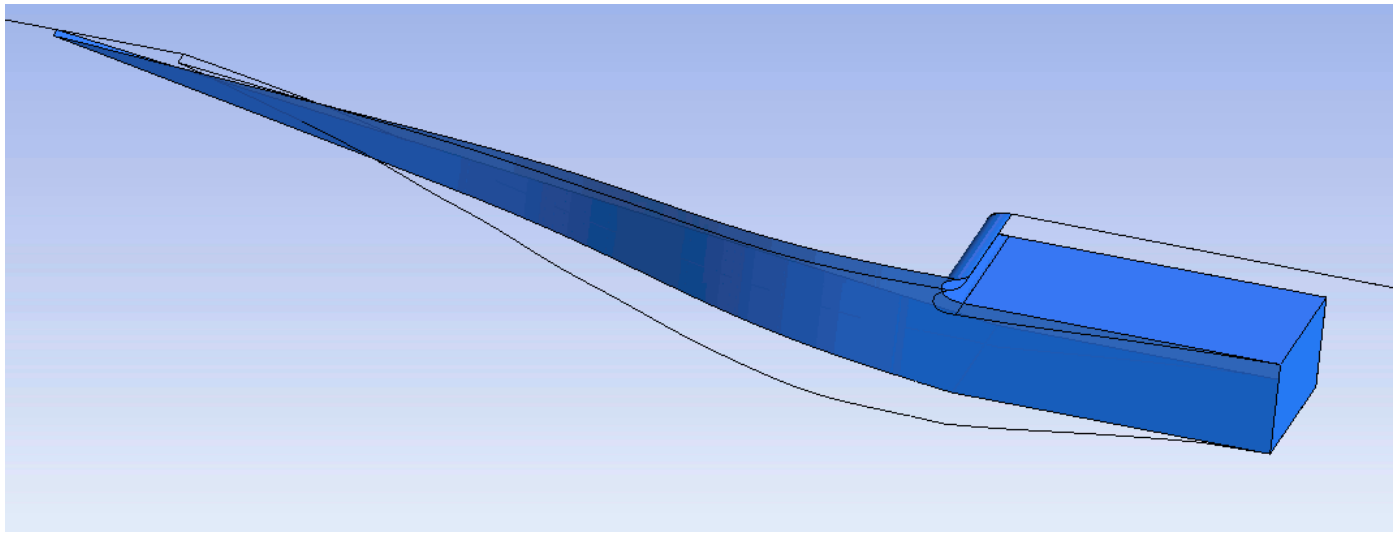
ROM: Optimization

- The tool allows to **export** the model as **FMU**
- The FMU model can be **integrated** with other Simulink models
- In this application the FMU model is linked to an **optimization algorithms** in Matlab -Simulink environment



Optimized Shape (1/2)

- Final shape and input parameter values:



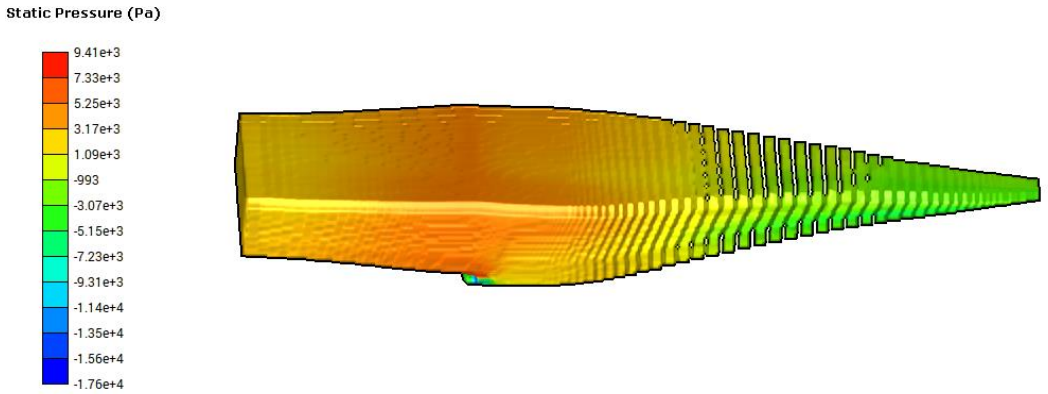
Cyl_o1	Cyl_o2	Cyl_o3	Cyl_o4	Cyl_o5	Length	Lateral	Localy1	Vel_in
4	*6*	*6*	*6*	*4*	*10*	*6*	*5*	*180 m/s*

- Comparison of outupt parameter on baseline and optimized shape:

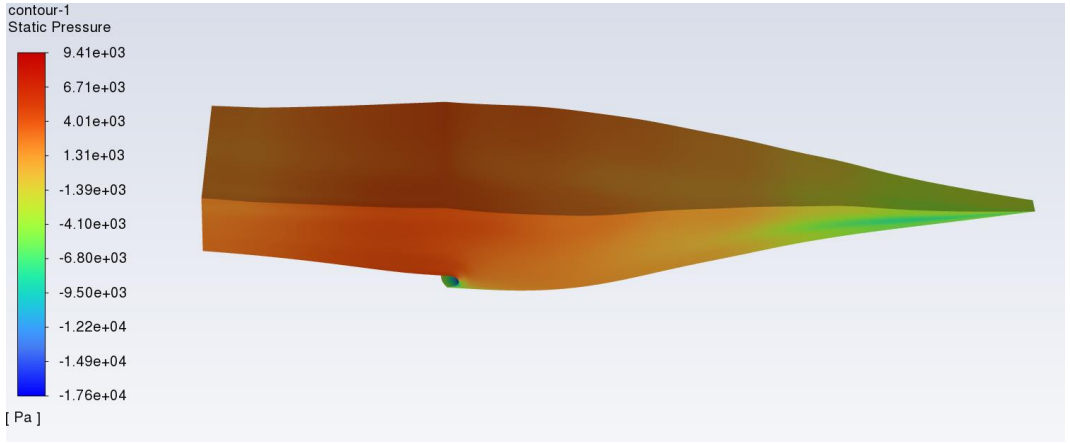
	Baseline	Optimized
Out Pressure	*664.5 Pa*	*1812.1 Pa*

Optimized Shape (2/2)

- Comparison static pressure on static ROM and CFD model



Static ROM



CFD

- Error on pressure output evaluation:

Error on optimized shape	Average Error on all DPs
3,1%	*1,9%*

Conclusions

- The proposed workflow allows to obtain a very accurate ROM
- The ROM can be used for the design and optimization of the NACA air intake
- The ROM can be integrated with the model of the entire airplane
- Mesh morphing technique and RBF Morph tool is critical to maintain the mesh topology unchanged and preserve the mesh quality

THANK YOU FOR YOUR ATTENTION

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