Optimisation of an IP and Console Duct Using Advanced Shape Deformation Technology

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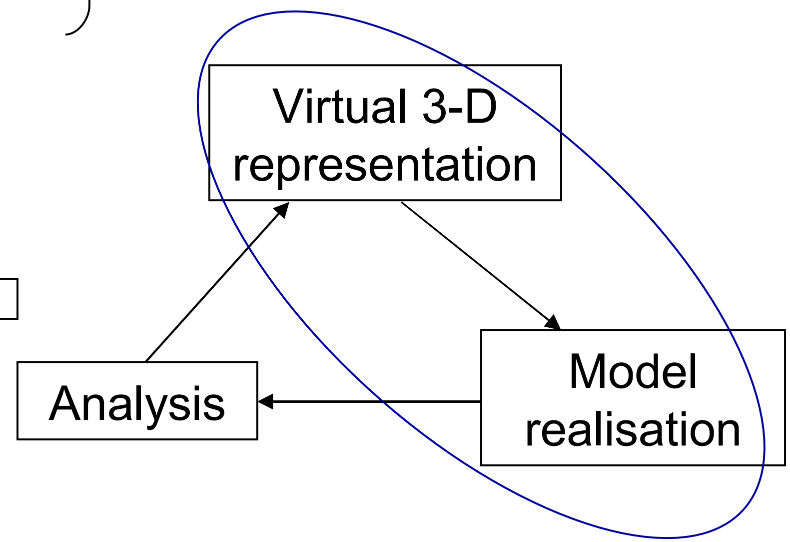
Optimisation in CFD Process

Procedures to optimise systems in Engineering:

- Experience
- One Variable at a Time
- Design of Experiments

In order to evaluate each design iteration, it is needed to perform the same steps:

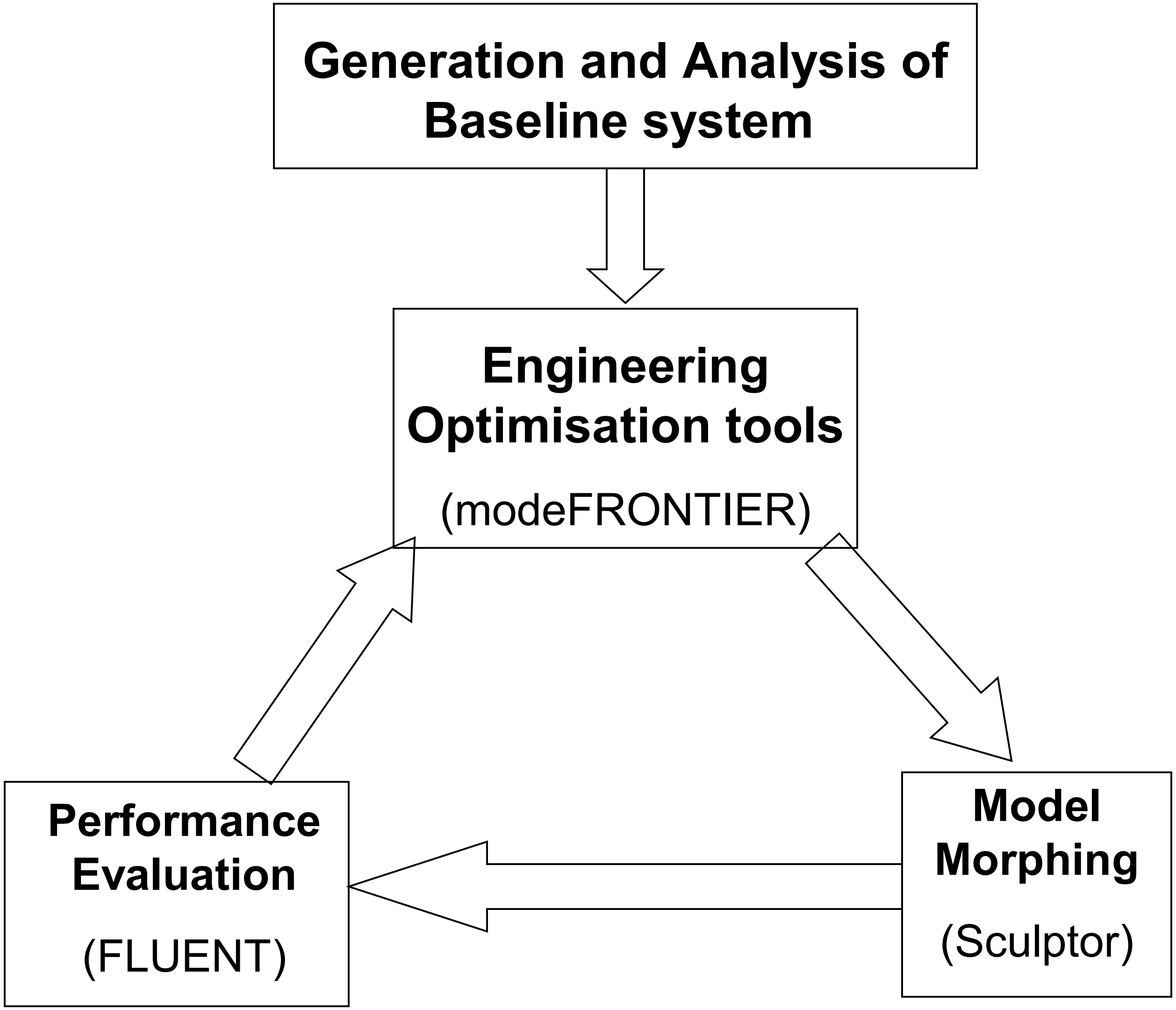


Steps to be performed for most of the design iterations. Hence optimisation process becomes time consuming and resource-intensive

Solution is to create a new prototype without spending time in pre-processing.

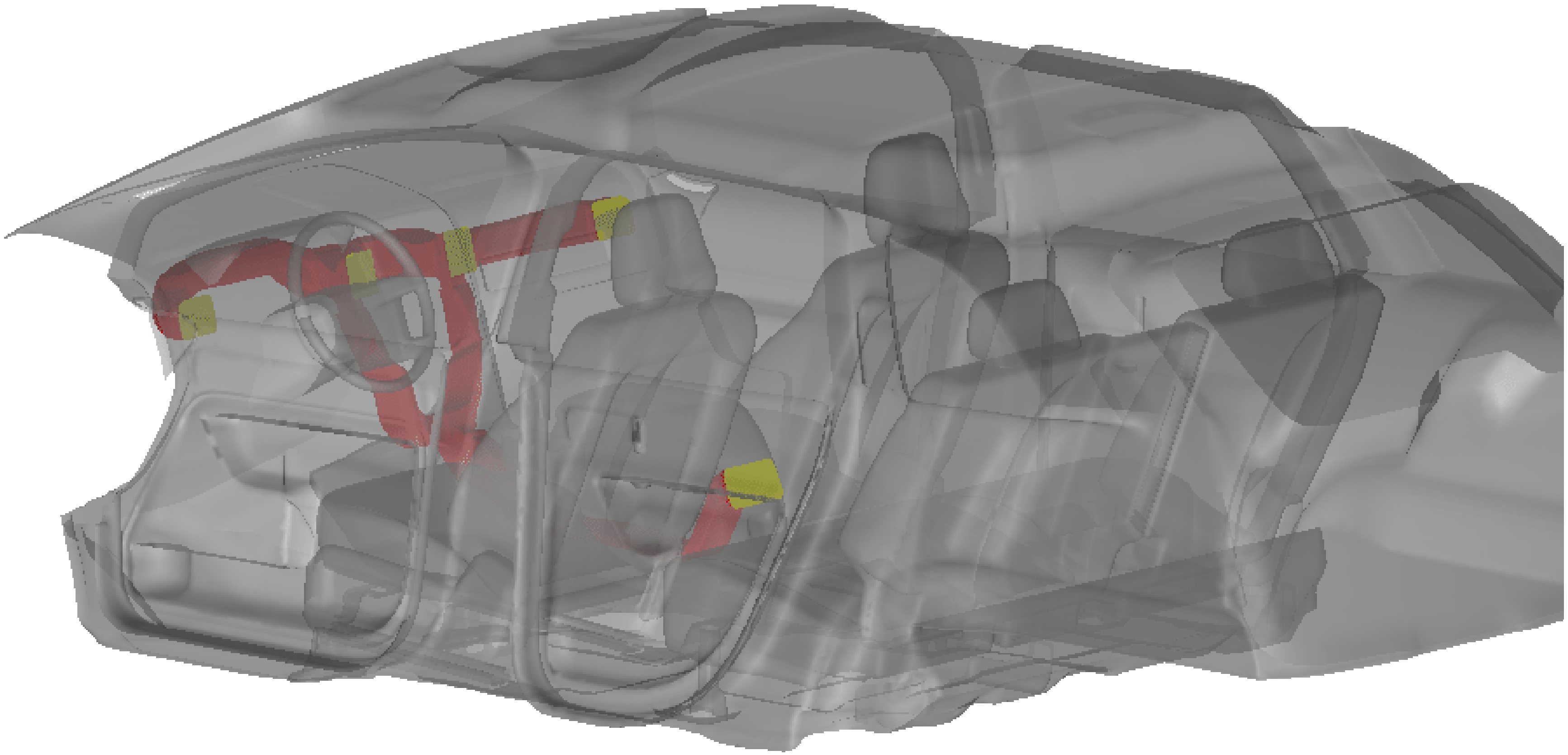
Model morphing

Integration of Optimisation in CFD process



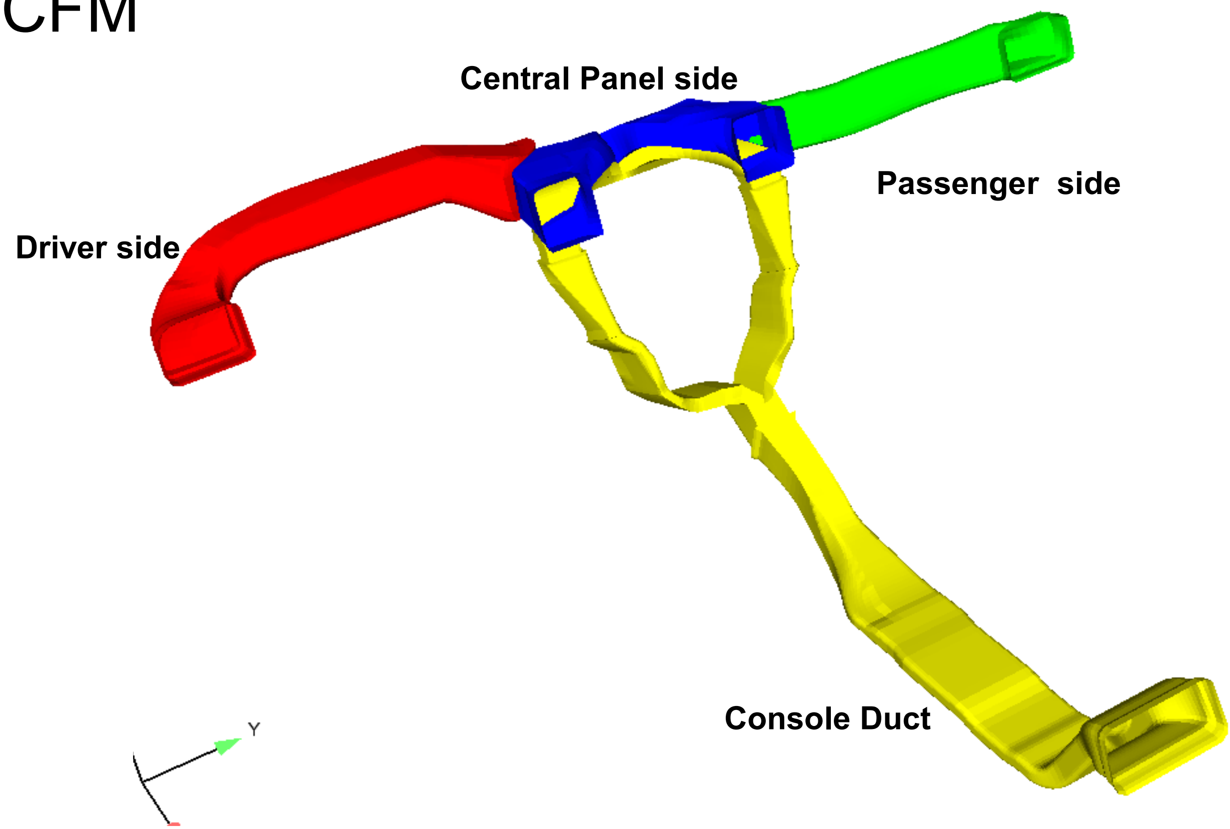
Goal

Flow optimisation of an HVAC Instrument Panel (IP) and a Console Duct



Overall Objective

- Increase the volume of air to the console register
- Minimize pressure drop within the existing package space
- Balance the air flow to the various registers. The volume flow rate difference between the various registers was not to exceed 10 CFM



Methodology

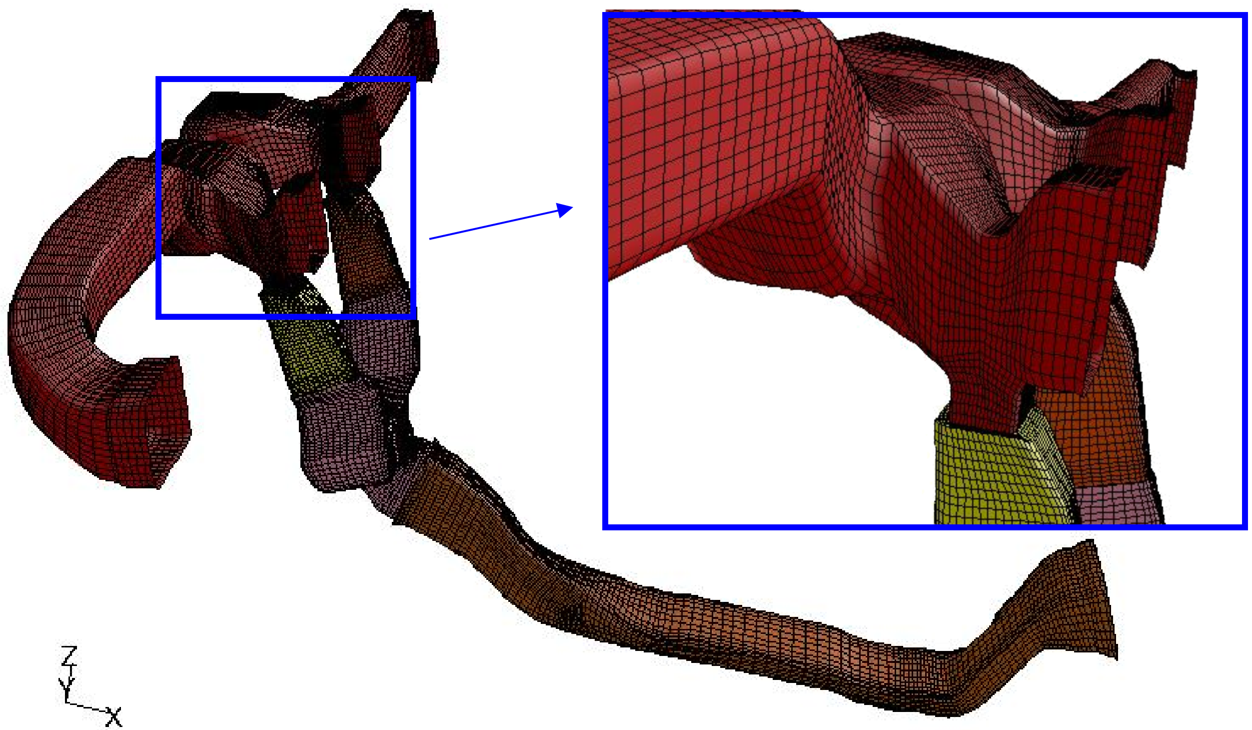
1. Analyze the baseline geometry with modern CFD methods to establish an initial air flow rate and pressure drop across the components
2. Parameterize the mesh model for use in optimization
3. Set-up an optimization algorithm to drive the process for improving design performance
4. Using DOE methods the optimizer tool generates an initial sample of points in the design space. Each of these generated points constitutes a different geometric design.

Methodology (Continued)

1. Using the parameterized model, the CFD flow domain is ‘morphed’ to create new designs
2. CFD analysis is performed on each of the designs.
3. The optimizer tool extracts the design performance data from the results and employs a Genetic Algorithm to modify each design
4. If the designs are still outside the optimal design criteria, this tool then generates a new set of sample points using the CFD results as inputs

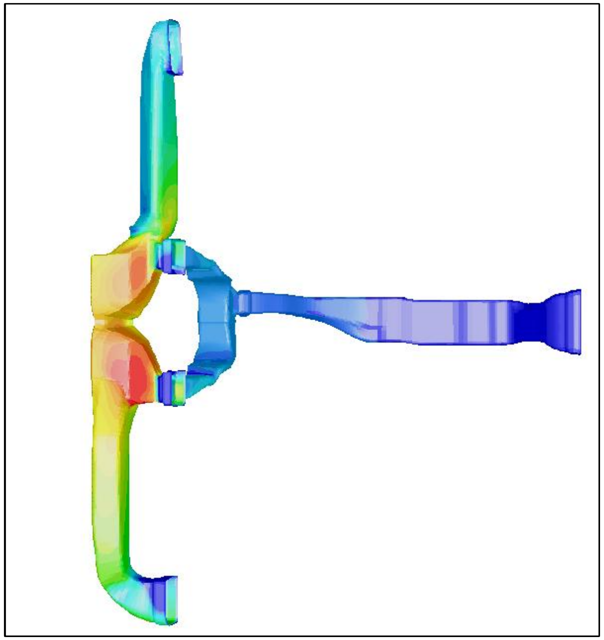
Description of the Model

- ANSYS ICEM HEXA was used to construct an all hexahedral model (about 600k cells).
- Mesh strategy was designed to allow for mesh deformation to the greatest possible extent without having to re-construct the mesh.

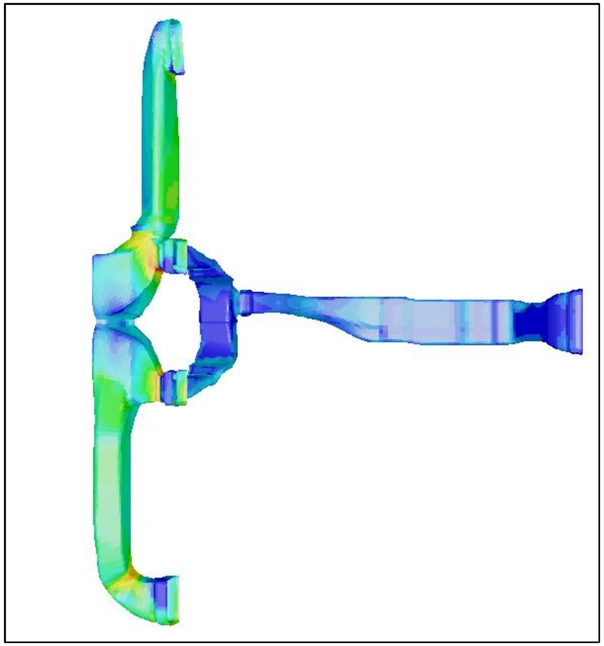


Simulation of Baseline

- The velocity profile from HVAC unit was used as BC for the inlet of the IP duct
- Steady state simulation was performed using standard wall functions, k-є turbulence model, and second order numerical schemes



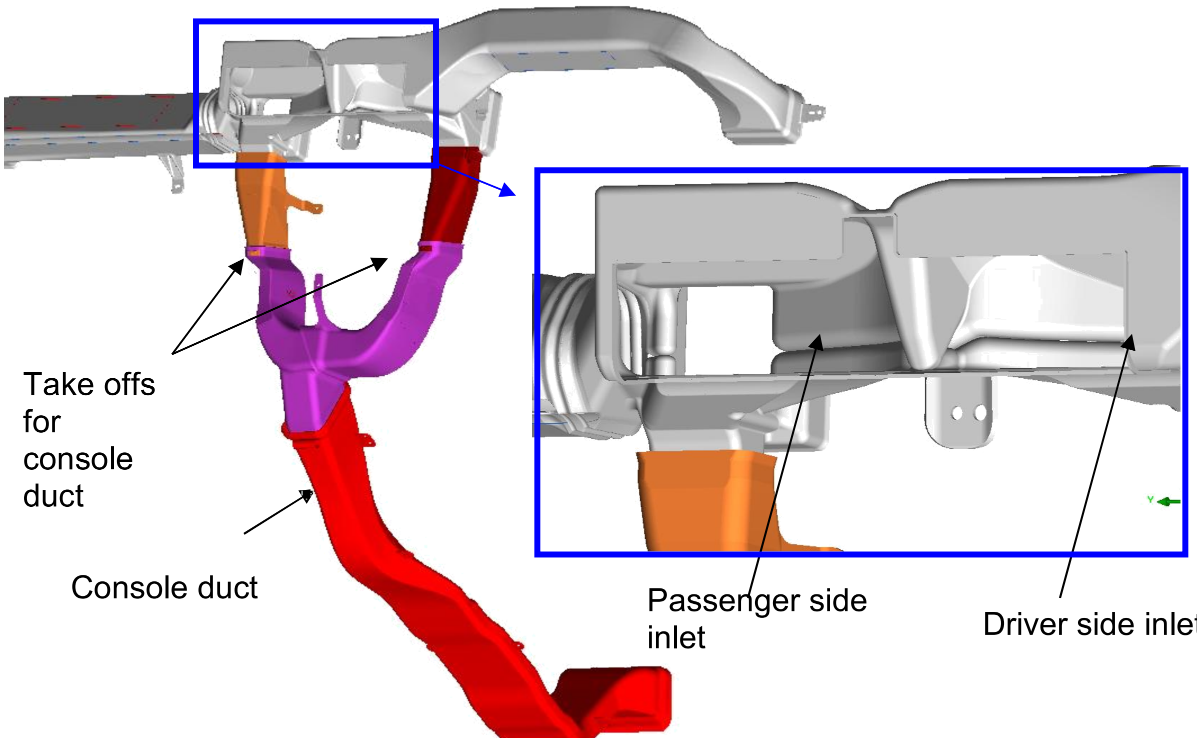
Pressure Contours

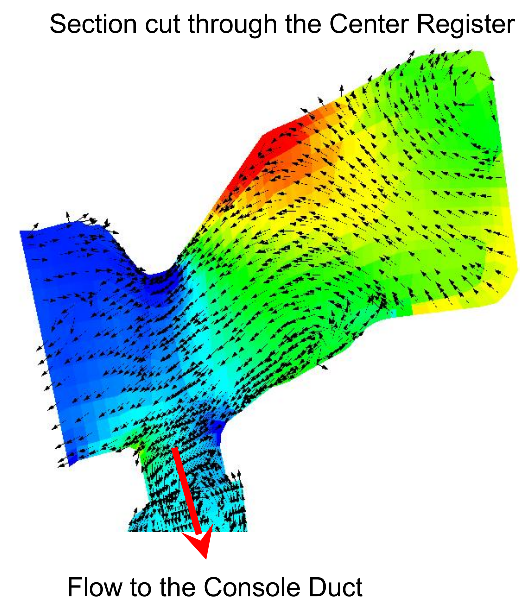


Velocity Contours

Simulation of Baseline

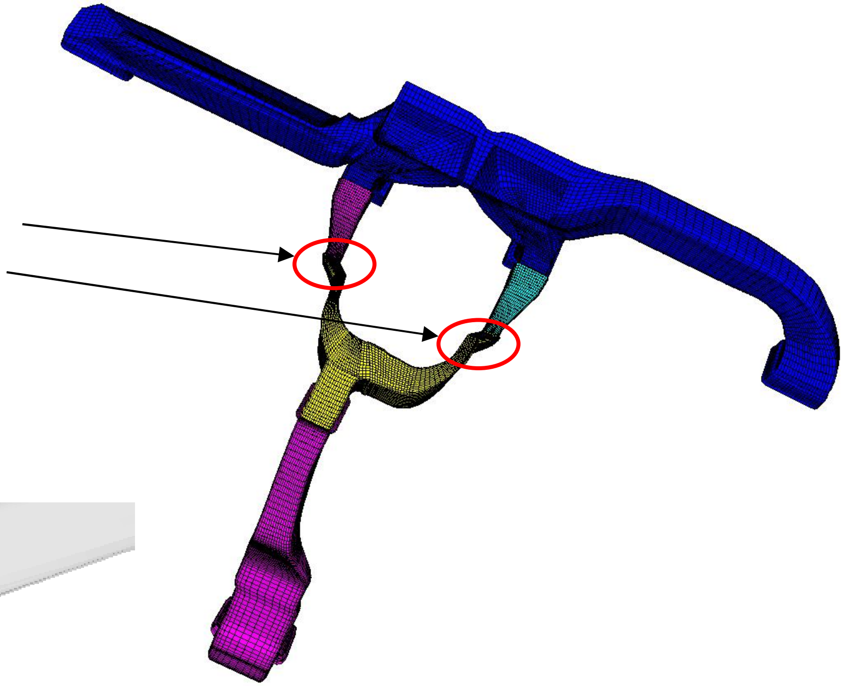
- The air enters the inlet regions and splits according to the pressure drop between the various ducts and registers
- Center registers are closest to the inlet with the lowest pressure drop and they are positioned to receive most of the volume flow rate which is delivered by the HVAC

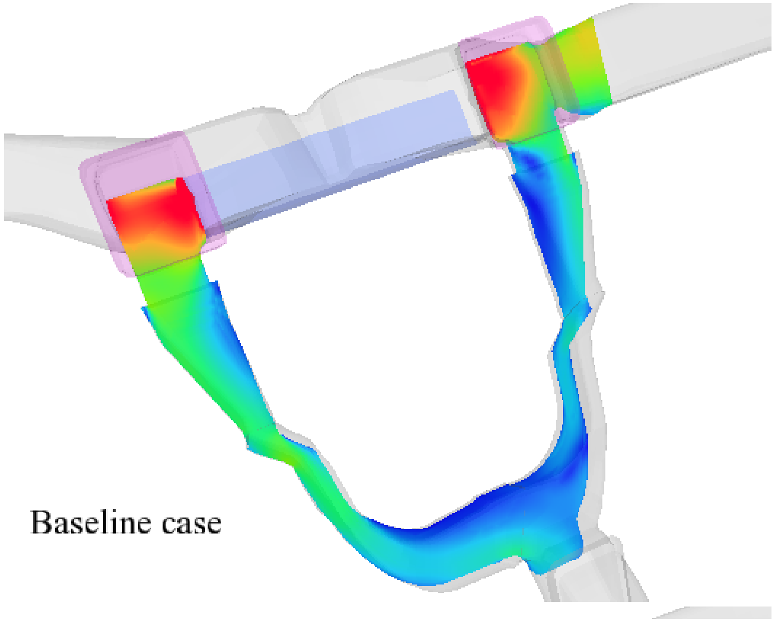




Results of Baseline

- The flow delivered to the console register was chocked at the two sides of the console frame

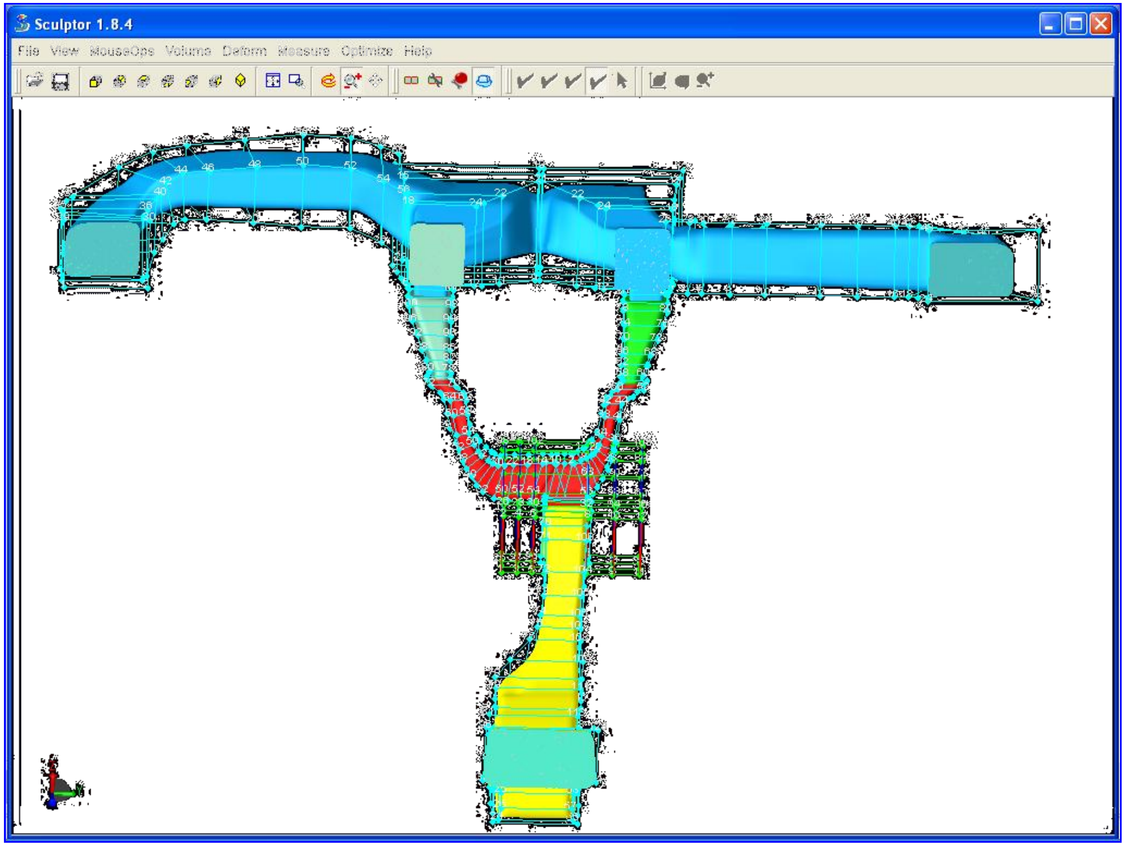




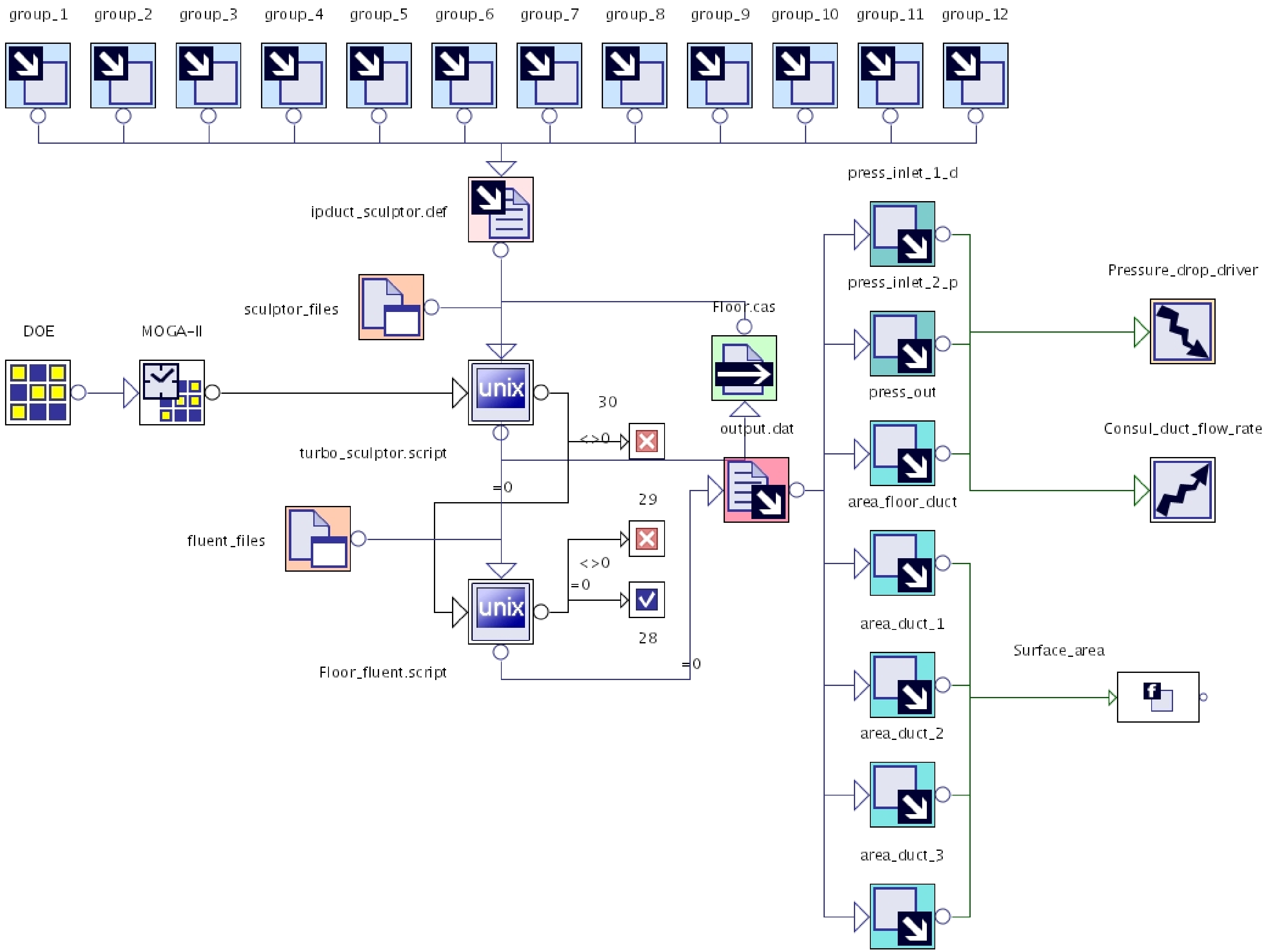
Baseline case

Mesh Morphing Process

- The ASD volume is created around the area of interest for the optimisation.
- Control points are grouped to coordinate the deformation. These groups will become the Design Variables (DV)
- The DVs are the design parameters used for the optimization process



Optimization Process



Optimization Process

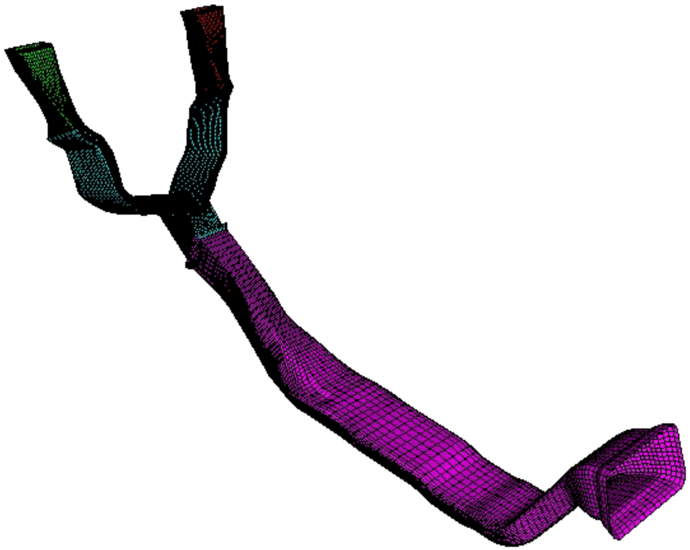
- The optimization was done in two steps:
  - Step one: The multi-objective generic algorithm (MOGA) was used along with pressure drop and flow split as the objectives to calculate the optimum geometry for the ducts. The flow split objective was achieved after 70 design iterations.
  - Step two: To speed up the calculations for the pressure drop objective, the flow split variables were switched to constraints.   The single objective algorithm was used to modify the console duct geometry.

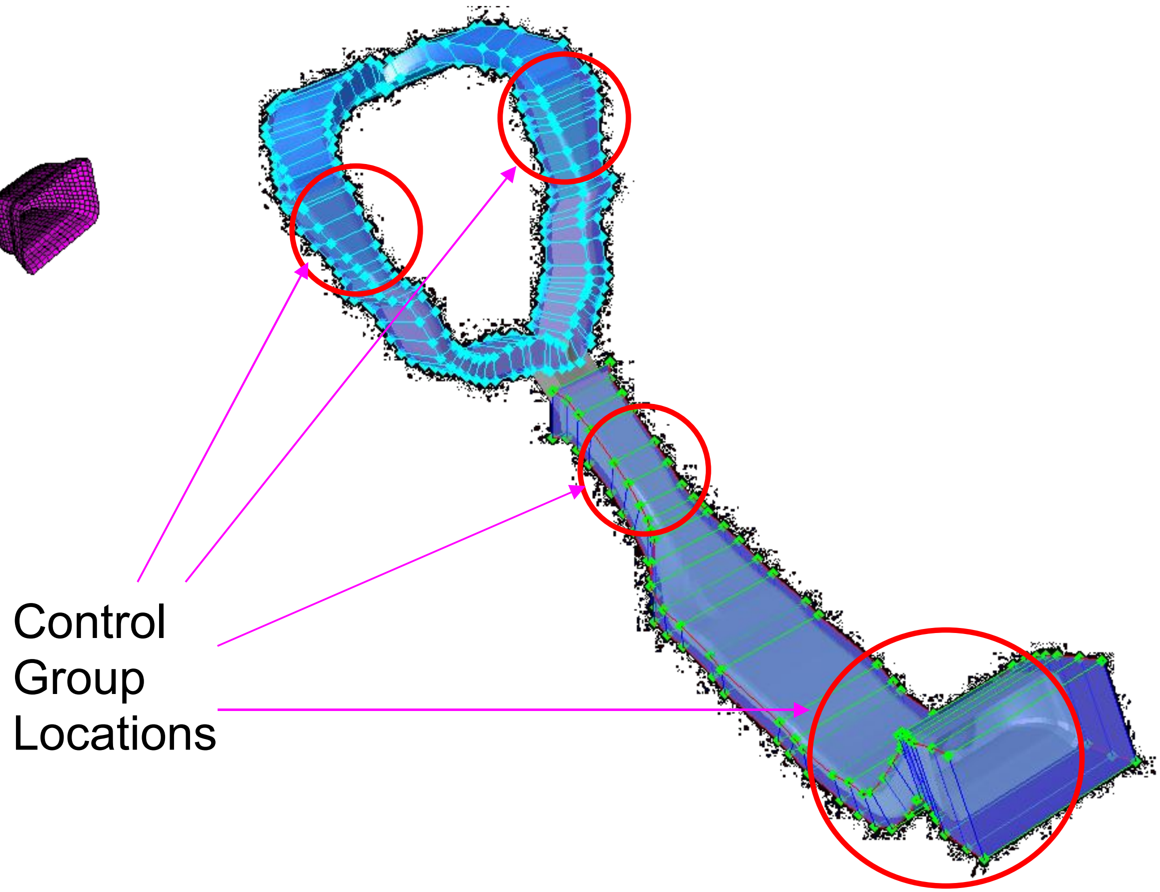
Optimization Process

- The overall optimization was performed with the following sub-domains:

1. The console duct region
2. The inlet region to the IP and Console Ducts (connection to HVAC outlet)

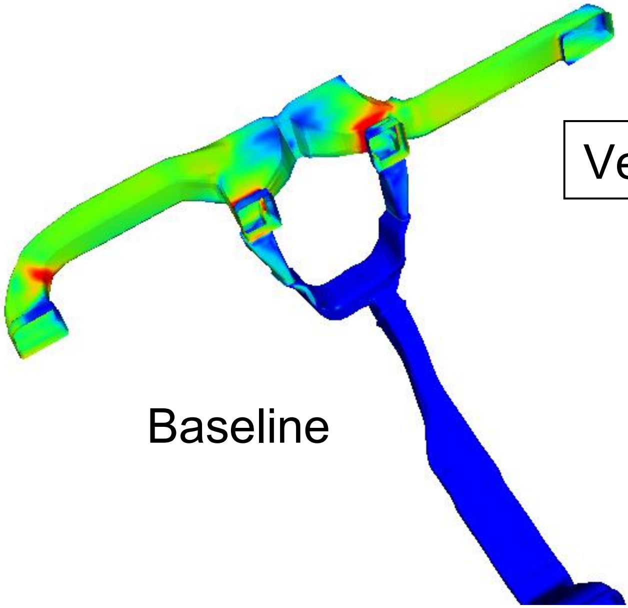
Console Duct Optimization



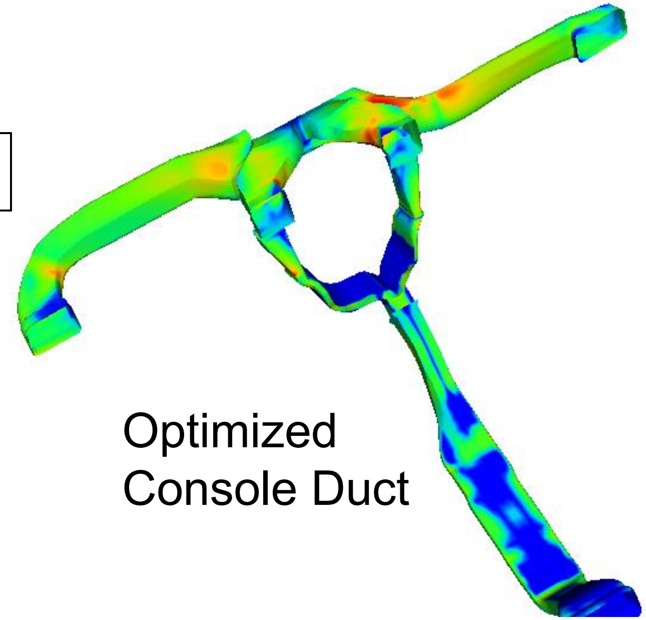


Results of Console Duct Optimization

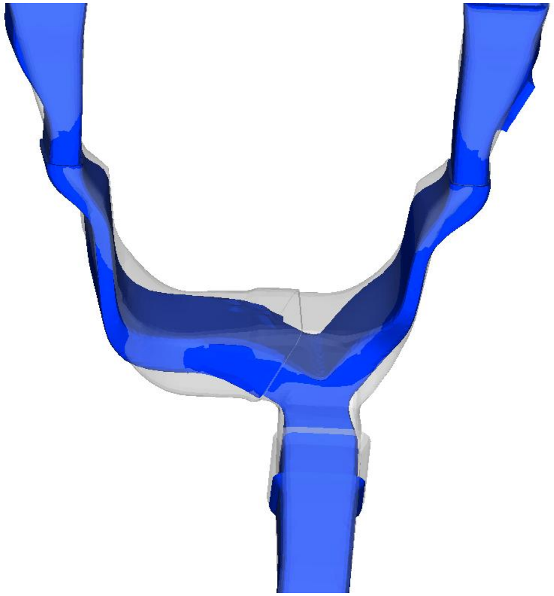
Velocity Profile



Baseline



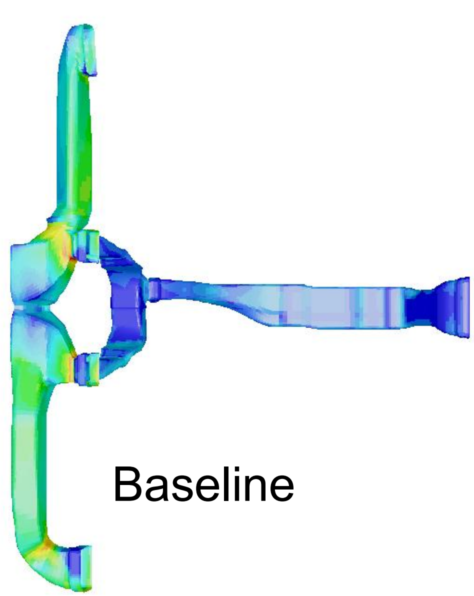
Optimized
Console Duct



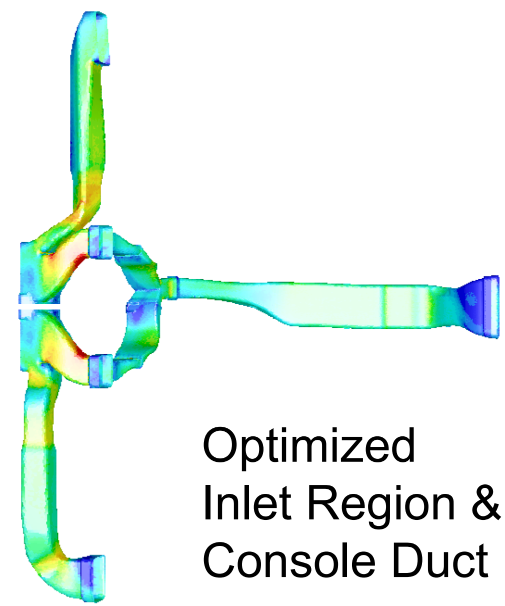
Grey: Baseline
Blue: Optimized

Optimization of the Inlet Region

- Following optimization of the console duct, the flow delivered to the console duct was still 50% of the required volumetric flow rate
- The IP inlet plenum had to be modified to split the flow more effectively to provide more air to the console duct.



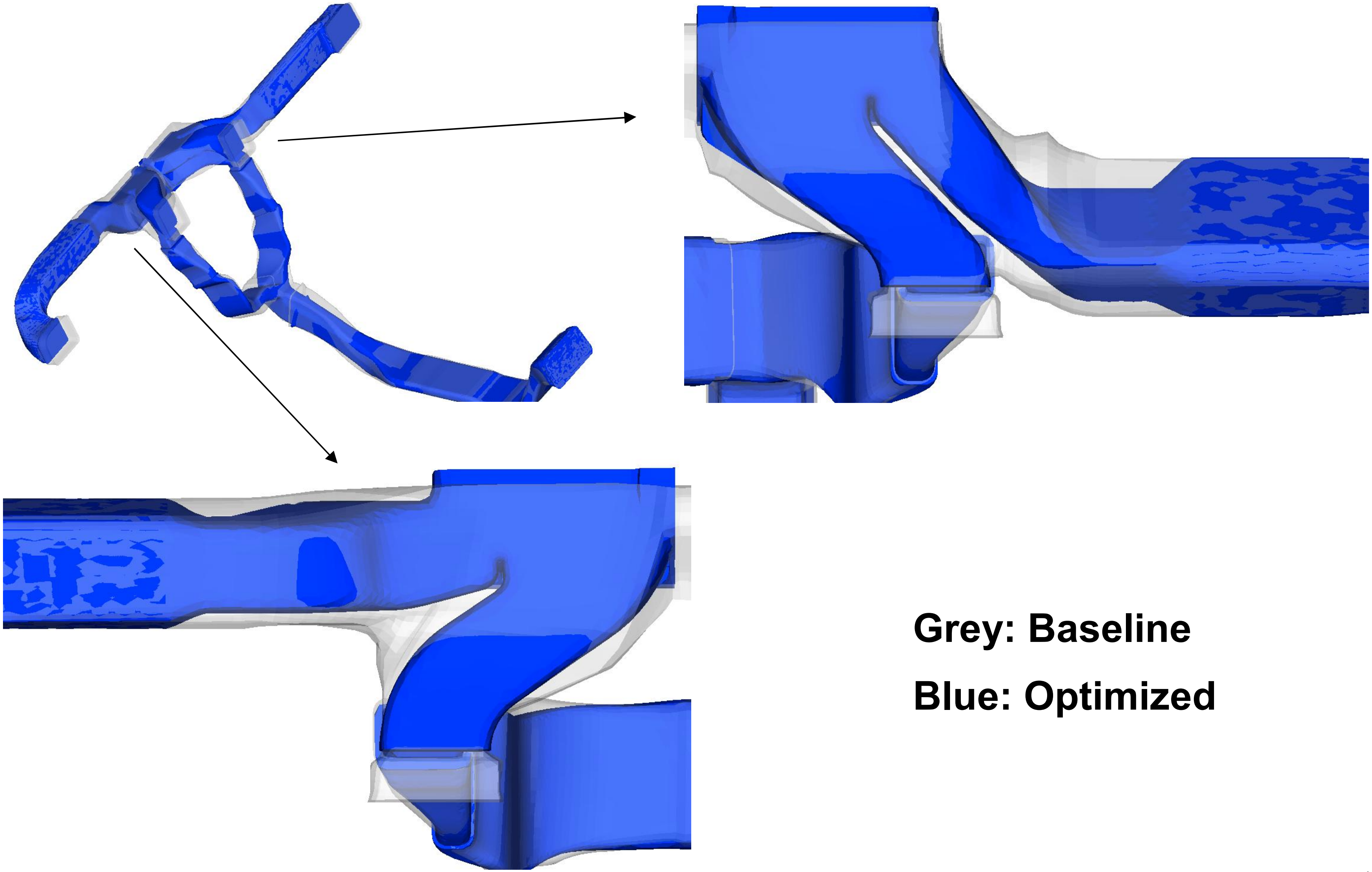
Baseline



Optimized
Inlet Region &
Console Duct

Velocity Contours

Optimization of the Inlet Region



Grey: Baseline

Blue: Optimized

Comparison of Baseline vs. Optimized Design

Conclusions

A new process for optimization has been described and applied to a multi-objective optimisation of an IP and Console Duct as follows:

- Key enablers:
  - Sculptor: used as morphing tool to generate geometrically-new design iterations without revisiting the CAD or any meshing tasks.
  - modeFRONTIER: coordinator of the optimisation process. Genetic Algorithms were used to create new generations, improving component performance.
- Advantages:
  - Reduced turnaround time with automation and model morphing.
  - Reduction of resources required as process works in batch mode (no user interaction).

Conclusions

- Outcome:
  - Optimisation was performed in two steps by dividing the entire flow region into two sub-domains
    - The Console Duct
    - The inlet to the IP and Console Duct
  - The flow delivered to the optimized console duct was increased by 250% compared to baseline
  - The pressure drop across the console duct was decreased by 9% even though a higher flow rate was delivered
  - As a confirmation of the optimized geometry, the optimized duct geometry was used to construct a stereo lithographic part to be installed on an HVAC unit to perform a bench test.
  - The results of the test were in very good agreement with the CFD results.

Thank you

Questions / comments ?

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