Integration of acoustic trim in FE structure borne noise optimization with SPL target

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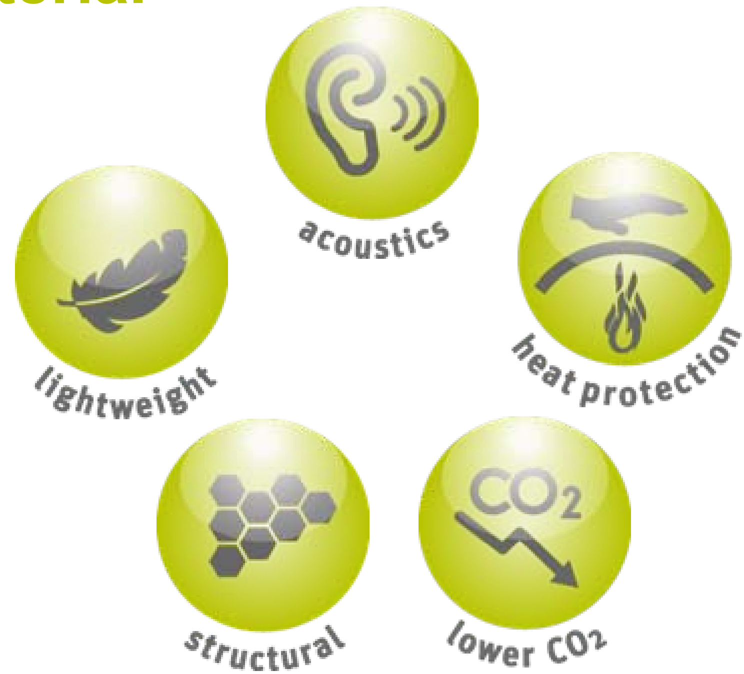
Agenda

1. CAE tool for structure borne optimization
2. Dichotomy Structural Target vs. Acoustic Target for a simple structure
3. ....and poro-elastic trim in the optimization
4. Simultaneus optimization of panel stiffness and poro-elastic treatment.
5. Further applications and next step

Autoneum and porous-elastic material

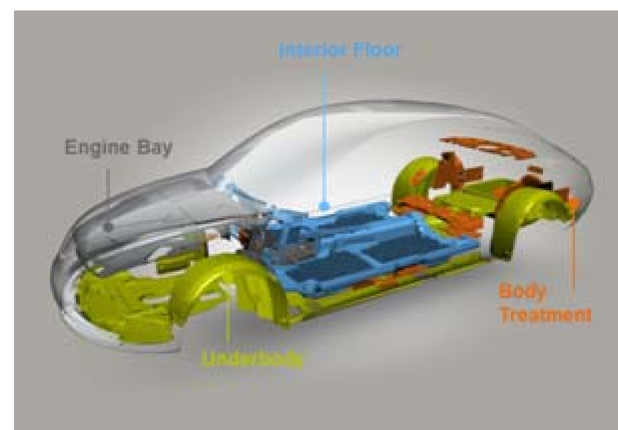
Head Quarter and Research & Technology
in Winterthur, Switzerland



Innovative and cost effective solutions for noise reduction and thermal management to increase vehicle comfort value.

Focus on product line interior floor: porous-elastic material behavior is key factor for the design and the optimization of inner dash, carpets, floor insulator and many others.

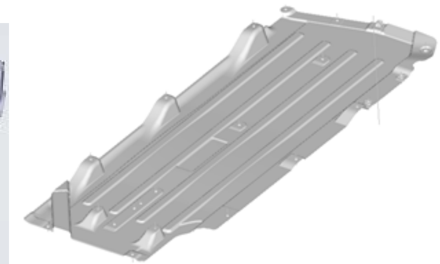
Optimization by in-house developed simulation tools



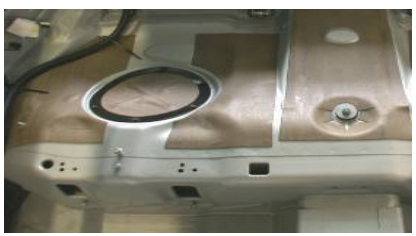
Use of CAE for acoustic package
The CAE tools from low to high frequencies

Design of damping layout for control of body vibration

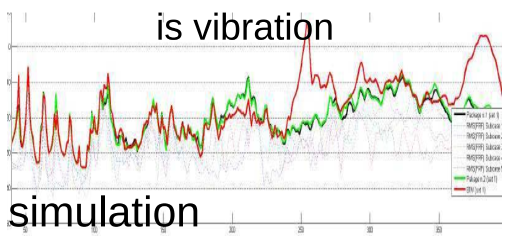
Design of carpet trim system for control of floor insulation/absorption



100 Hz 1kHz 10 kHz

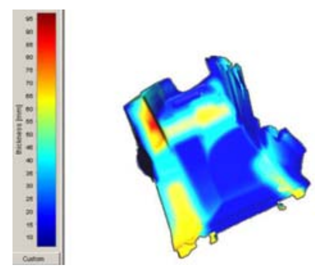


Performance measurable is vibration

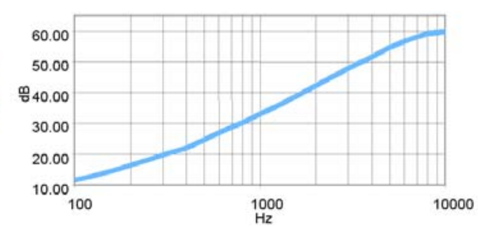


CAE Tool: FE based simulation

Nowadays, it is also possible to assess performance on SPL

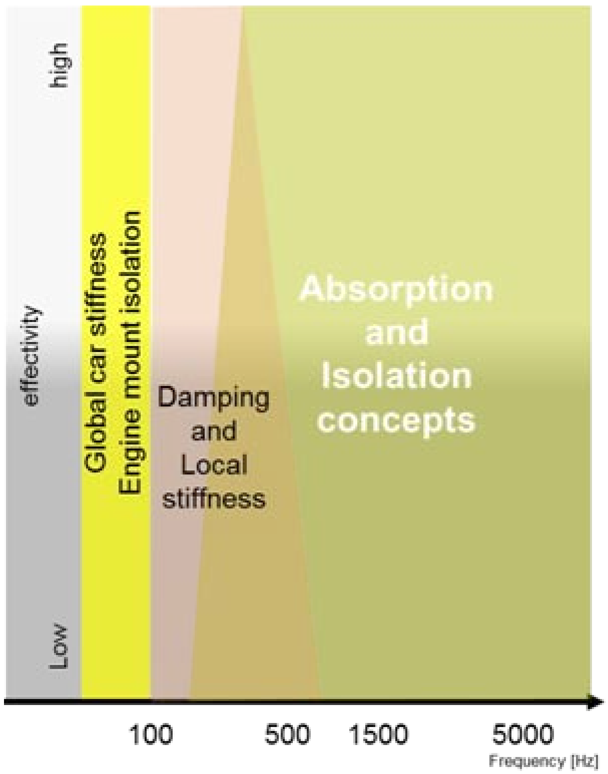


Performance measurable is SPL



CAE Tool: TMM and S.E.A.

Design of lightweight NVH package at LF-MF
Damping, Stiffness and Trim design



- In 100-1000Hz combined influence of:
  - Local stiffening
  - Local damping
  - Trim impedance

- Trim has effect on panel vibration (evaluation of panel local stiffness and local damping).
- Trim influences (reduces more or less) the radiated noise due to its transmissibility

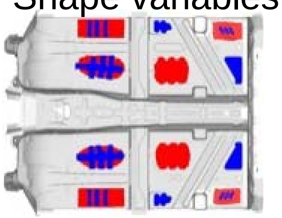
⇒ Design of light weight dash/floor: there is a need to support from the methodological point of view the simultaneous design of body NVH together with the trim.

Design of lightweight NVH package at LF-MF
GOLDTrim: GOLD method with integrated TREASURI2

GOLD
Panel stiffness optimization

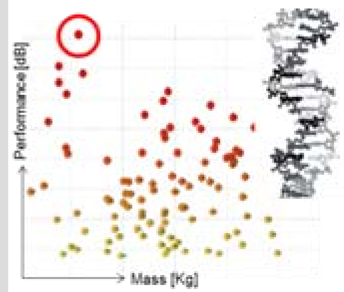
Damping variables

Shape variables

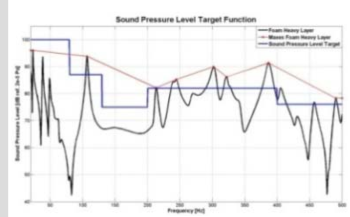


SOL111 Loops

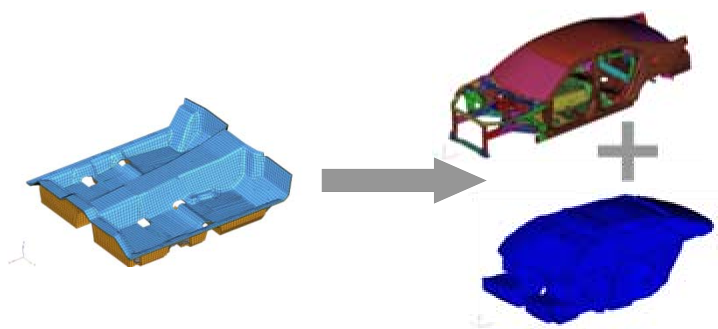
GOLD-Trim



SPL target



Treasuri2
Porous trim parts into vehicle NVH FE models.



MSC Software

Nastran PEM integration in SOL111 with TREASURI2 dmap

Optimized damping package
Optimized body structure

SPL
Trimmed vehicle simulation

D. Caprioli, C. Gaudino, L. Ferrali, L. Hao: “Shape and damping automatic vibroacoustical optimisation of automotive panels by means of GOLD”, Rieter Automotive Conference, 2005

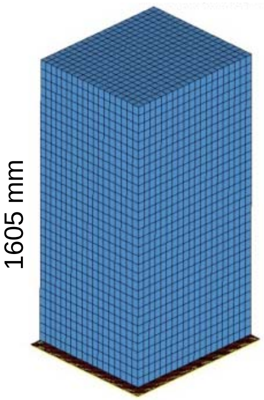
C.Bertolini, L.Guj, F.A.Bassi, K. Misaji and F. Ide, “Treasuri2/FE: a tool for the FE simulation of sound package parts fully integrated in Nastran”, Proceedings of SAE 2009, Traverse City, 2009 autoneum

CAE tool	Description	Main Feature	Why has been used
GOLD with Structural Target	▪ Optimization: Panel stiffening (damping and stiffening) ▪ Target: Vibrational response	structural, functionality	**In the LF range, highly dominated by structural borne phenomena, is it valuable to have an acoustic target instead of a structural target?**
GOLD with Acoustic Target	▪ Optimization: Panel stiffening (damping and stiffening) ▪ Target: Sound Pressure Level	acoustics, functionality	
GOLD with TRIM included	▪ Optimization: Panel stiffening (damping and stiffening) ▪ Target: Vibrational response or Sound Pressure Level ▪ Effect of poro-elastic trim.	structural, acoustics, functionality	**Is it valuable to add the trim in the optimization, when it is not a variable of the optimization?**
GOLDTrim	▪ Optimization: Panel stiffening (damping and stiffening) and poro-elastic trim ▪ Target: Vibrational response or Sound Pressure Level ▪ Poro-elastic trim part of the optimization	structural, acoustics, functionality, lightweight	**How much can we gain by including the trim in the optimization in terms of weight reduction or performance improvement?**

Simple Test case: plate/box system

SIMULATION

Number DOF	
Aluminium plate	**Cavity**
~18k	~7k
Modal base up to 800 Hz (for optimization until 600 Hz)	
Aluminium plate	**Cavity**
122 modes	76 modes

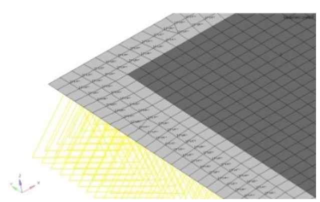


1605 mm

700x800 mm2

The boundary of the plate are clamped and they are not coupled with the cavity. (SPC 123456 on two lines of nodes).

The boundary of the cavity have not to be specified in Nastran. They are the natural condition for cavities (grad P = 0).



TESTING

Test case of a flexural plate attached to the bottom of a rectangular acoustic box :

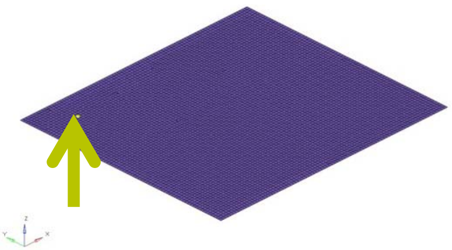
-Spring-suspended decoupled box with composite sandwich walls (rigid walls)

-Aluminum test plate (1.2mm thick) clamped along the edge by numerous screws

Suspended box with plate, 2m above ground:

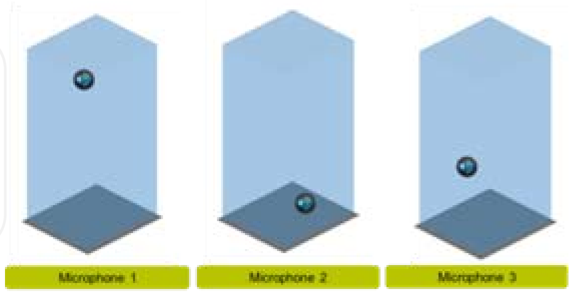
Simple Test case: plate/box system

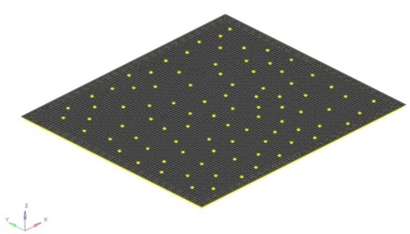
SIMULATION	TESTING



LOAD POINT
Force dir. Z

ACOUSTIC RESPONSE SET



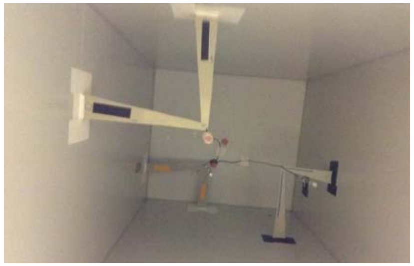


STRUCTURAL RESPONSE SET

- Excitation of the plate at one point by shaker with force and acceleration sensor

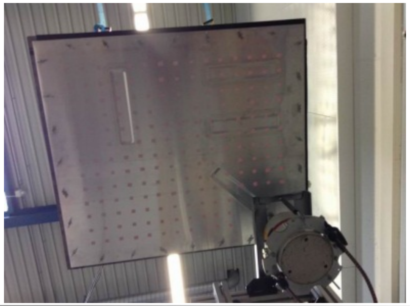
Shaker attachment to the screwed-on plate

- Measurement of plate vibrational response at a grid of 183 points by laser vibrometry (Polytec 2D-scanning head)
- Measurement of the acoustic pressure field in the box cavity at 3 points by microphones



3 microphones in the box cavity

Test plate with a grid of 183 reflectors

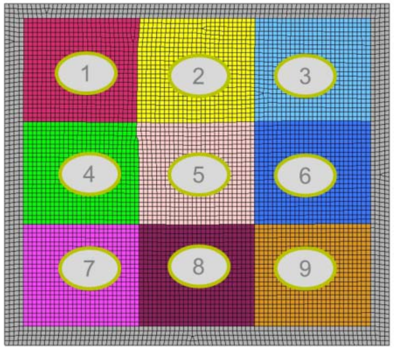


Simple Test case: plate/box system
Optimization Variable Description

DAMPING => 262144 combination (4^9)

9 different possible damping design regions have been individuated.

For each of them **4** different configurations are possible.

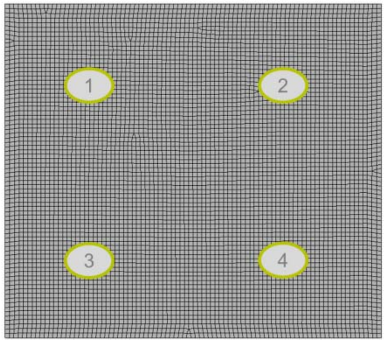


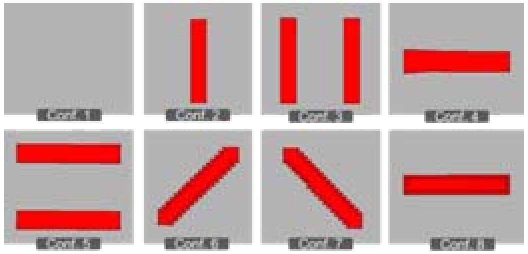
DAMPING MATERIAL DATA (Updated 08/2013)			
Name	Nero Acoustic	122/200 conf A	122/200 conf B
Thickness [mm]	1.68	2.00	2.30
Area W. [kg/m²]	2.50	3.60	4.20
Usage	Autoneum lightweight damping with high level performance	Conventional Bytumen material with medium performance and medium weight	Conventional Bytumen material with high performance and high weight

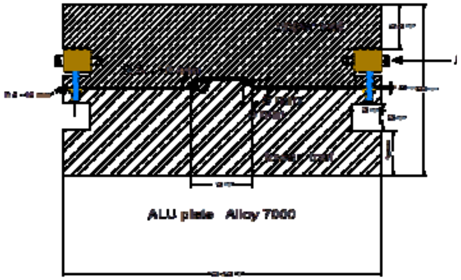
SHAPE (stiffening) => 4096 combinations (8^4)

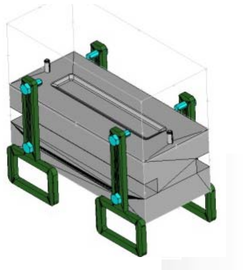
4 different possible shape design regions have been individuated.

For each of them **8** different configurations are possible.

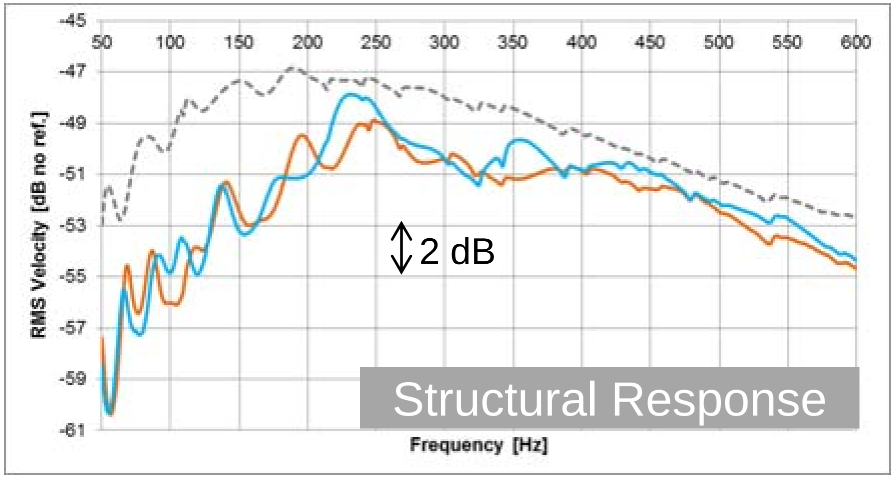


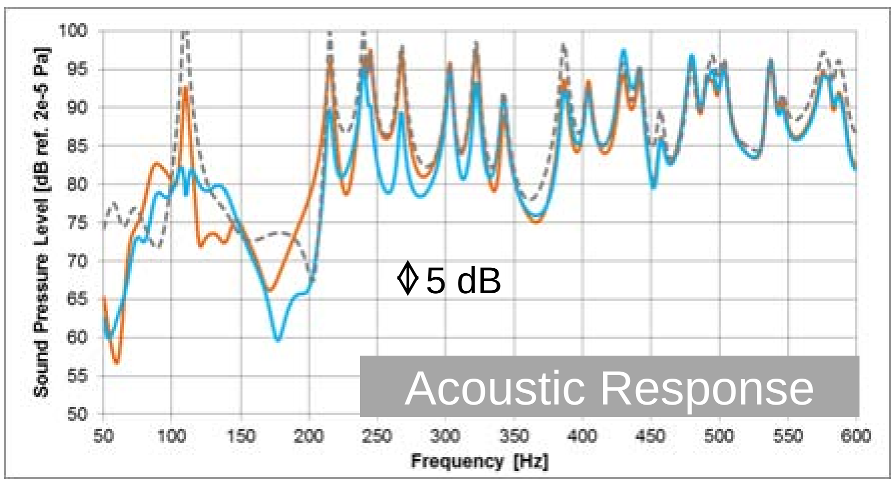






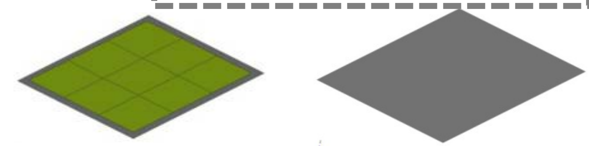
Acoustic target or structural target?





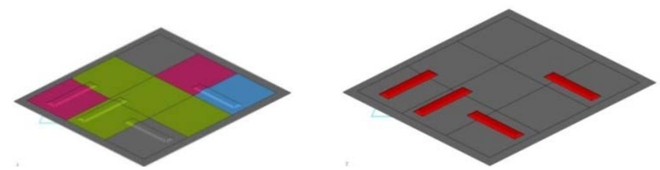
Reference

Weight 1.35 kg



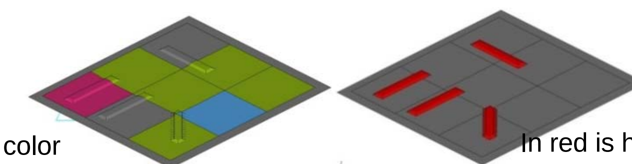
Optimum with a Structural Target

Weight 1.38 kg



Optimum with an Acoustic Target

Weight 1.23 kg



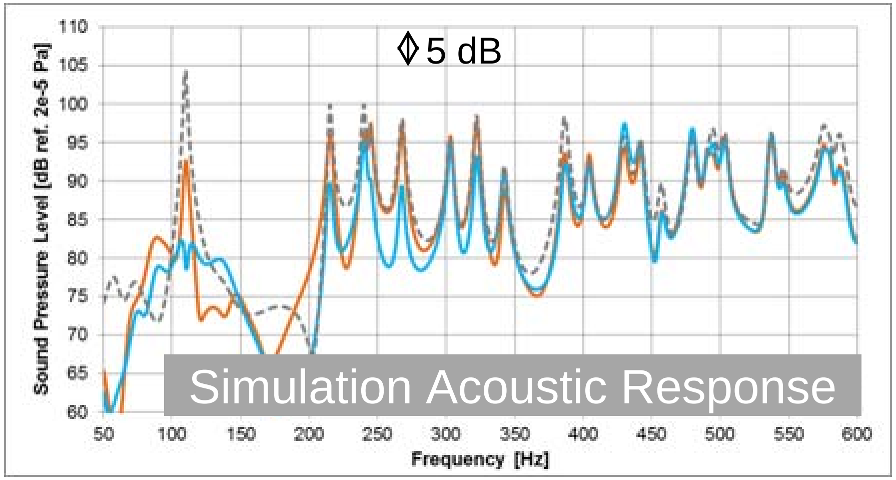
Different color correspond to different material

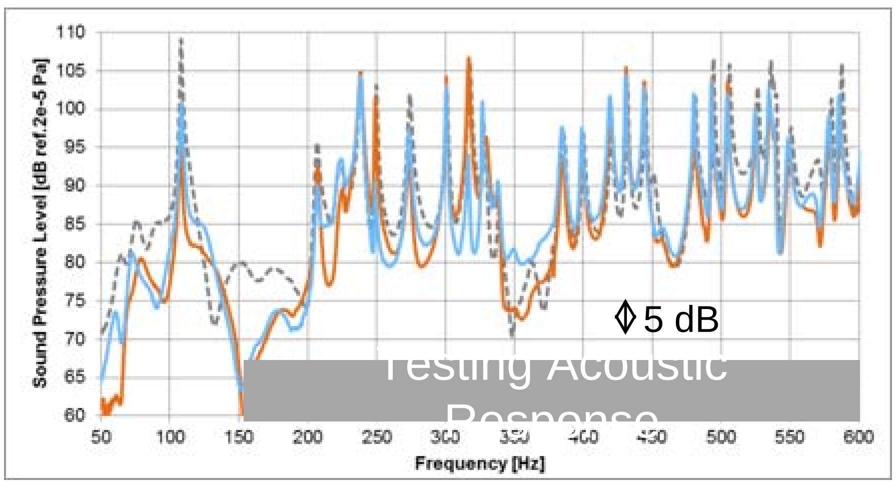
In red is highlighted the position and the pattern of the beads

Better performance with lighter damping package, when an acoustic target is used

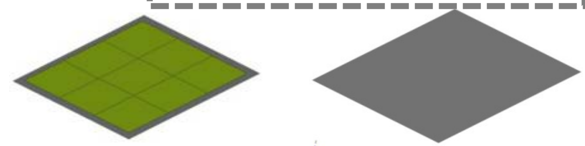
Acoustic target or structural target?

Validation

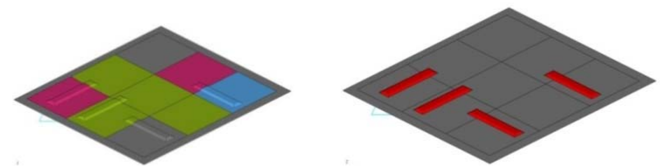




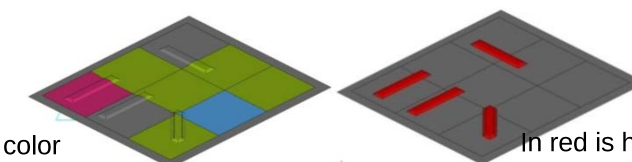
Reference — Weight 1.35 kg



Optimum with a Structural Target — Weight 1.38 kg



Optimum with an Acoustic Target — Weight 1.23 kg



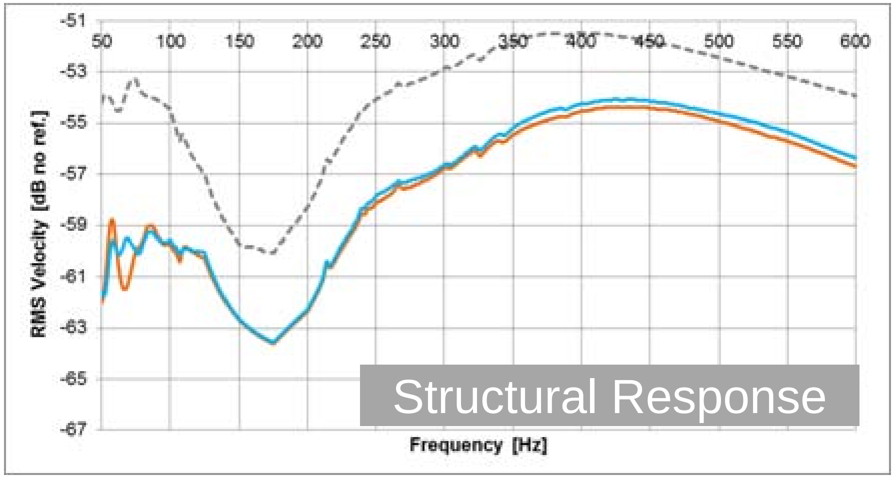
Different color correspond to different material

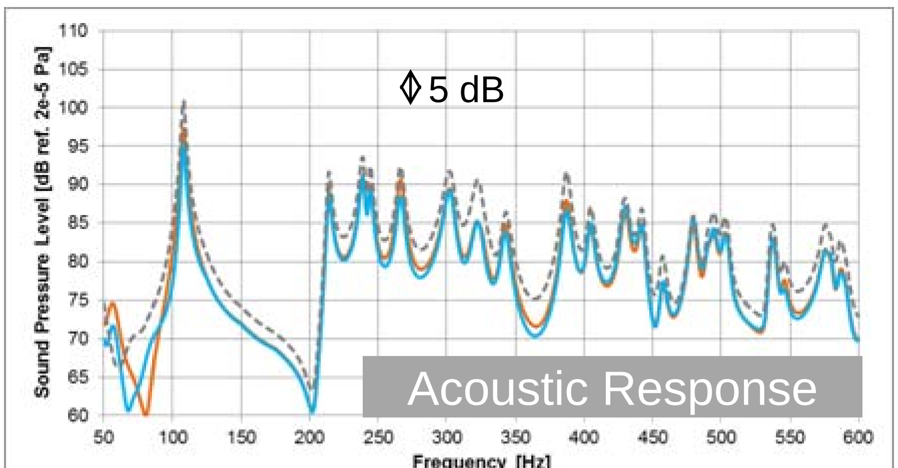
In red is highlighted the position and the pattern of the beads

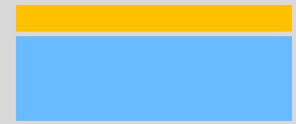
Better performance with lighter damping package, when an acoustic target is used

Acoustic target or structural target?

Including the trim after the optimization





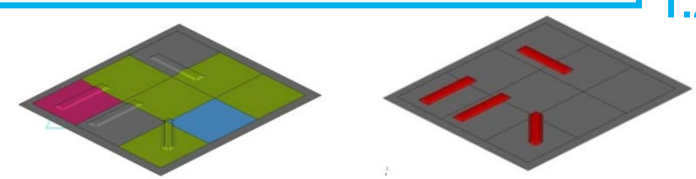


The results in previous page are re-computed, adding a trim (Foam HL) after the optimization

Reference — **Weight 1.35 kg**

Optimum with a Structural Target — **Weight 1.38 kg**

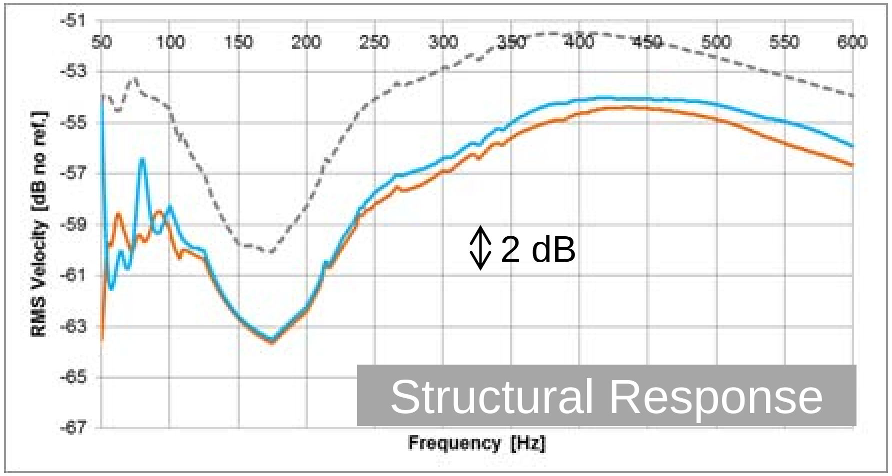
Optimum with an Acoustic Target — **Weight 1.23 kg**

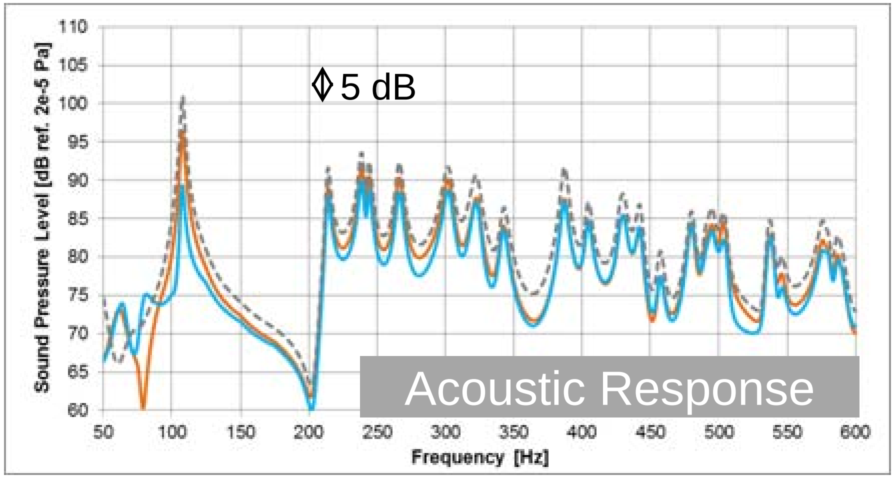


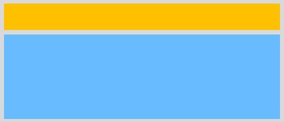
Better performance with lighter damping package, when an acoustic target is used

Acoustic target or structural target?

Presence of the trim during the optimization

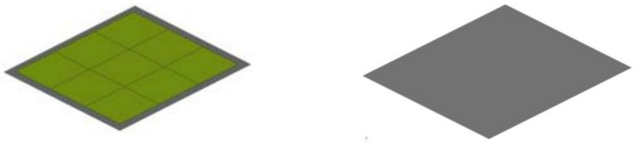




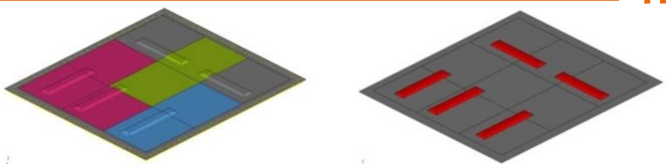


The same optimization is re-run, but now the trim (Foam HL) is always present on the plate.

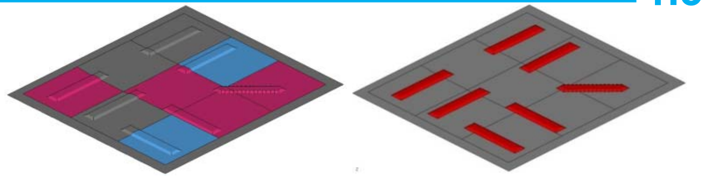
Reference — **Weight 1.35 kg**



Optimum with a Structural Target — **Weight 1.44 kg**



Optimum with an Acoustic Target — **Weight 1.39 kg**



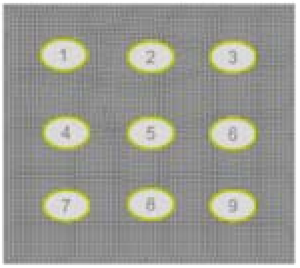
Better performance with lighter damping package, when an acoustic target is used

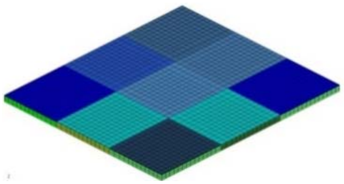
GOLDTrim trim damping shape optimization

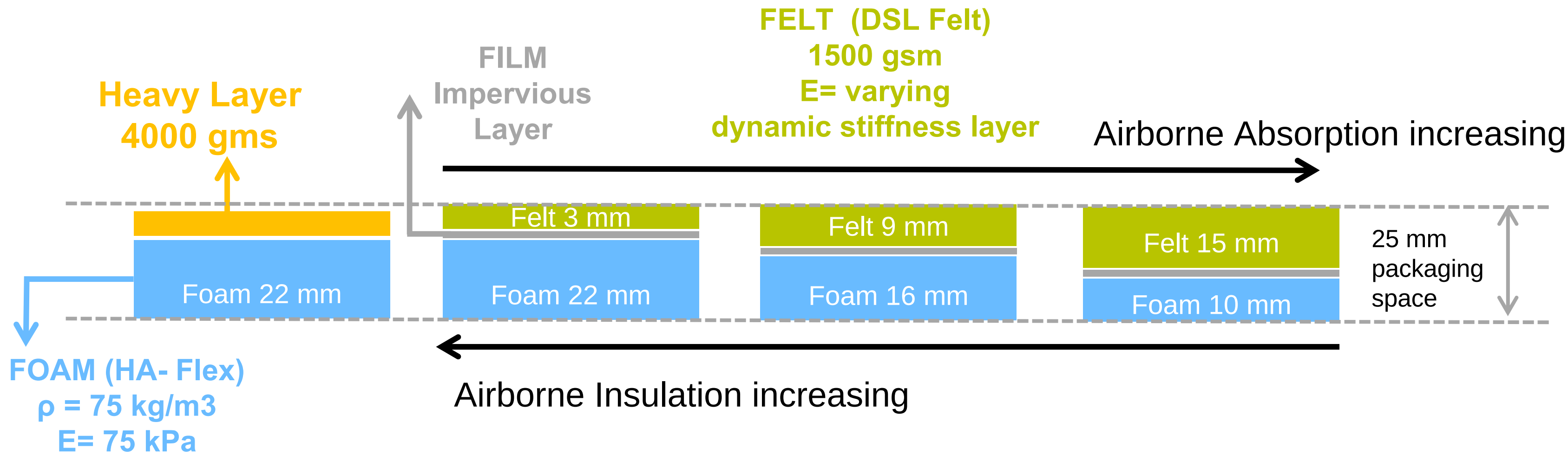
Trim Optimization Strategy

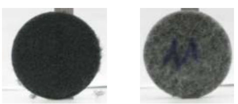
9 different possible trim design region have been individuated.

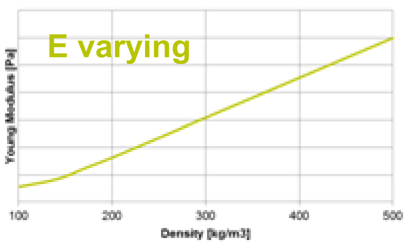
For each of them **4** different configurations are possible (total 262144 combinations).











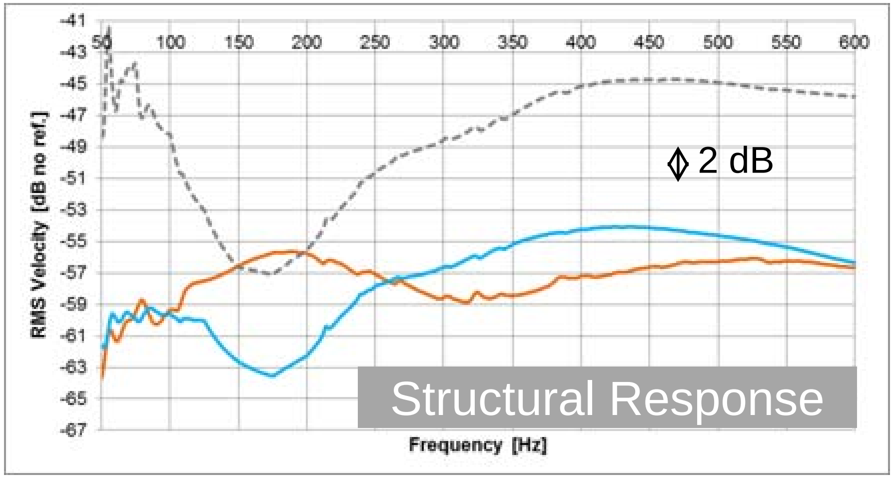
Autoneum Porous Material Description (necessary to create 3D FE model for TREASURI simulation)

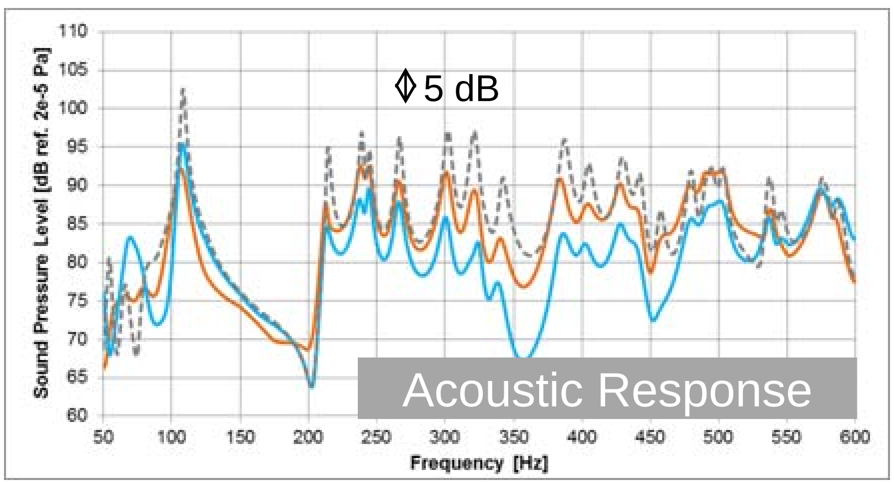
Treatment weight [kg]	1 Pad	9 Pads – Full coverage
Foam HL	0.45	4.08
Foam Felt 3	0.23	2.08
Foam Felt 9	0.19	1.74
Foam Felt 15	0.17	1.53

Optimization: Panel stiffening (damping and stiffening) and poro-elastic trim → GOLDTrim

D
- Nero Acoustics
- 122/200 3.6 kg/m^2
- 122/200 4.2 kg/m^2

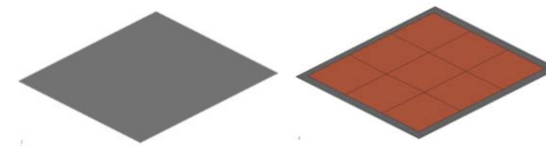
T
- Foam 22 mm +Heavy Layer 2.5 mm
- Foam 22 mm +Felt 3 mm
- Foam 10 mm +Felt 15 mm
- Foam 16 mm +Felt 9 mm





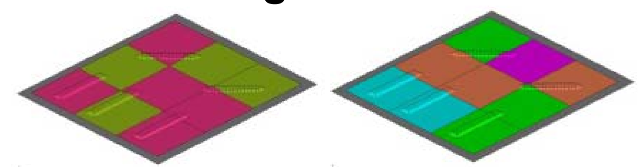
Reference

Weight 4.1 kg
4.1. kg NCT +
0 kg
damping

D  T

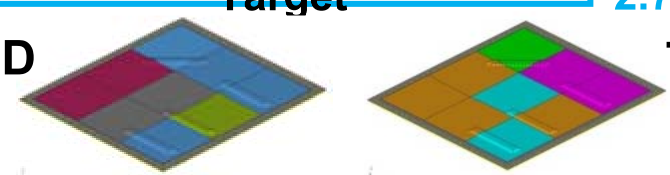
Opt. with a Structural Target

Weight 4.48 kg
2.61 kg NCT +
1.87 kg
damping

D  T

Opt. with an Acoustic Target

Weight 4.25 kg
2.77 kg NCT +
1.48 kg
damping

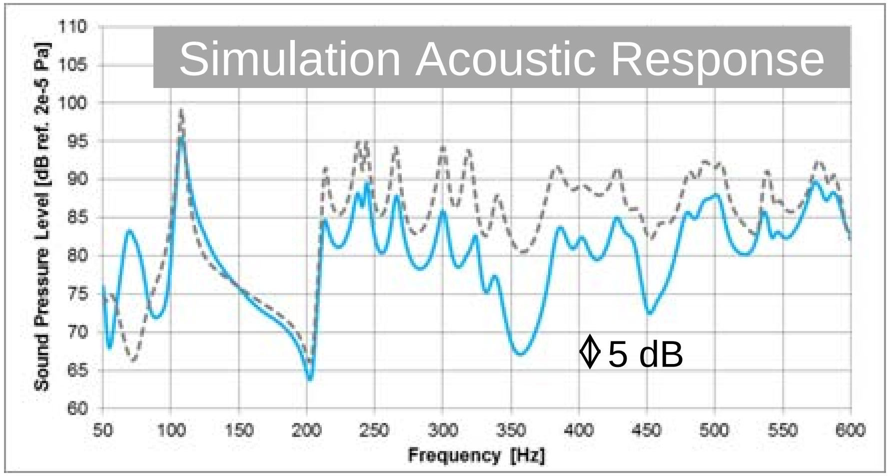
D  T

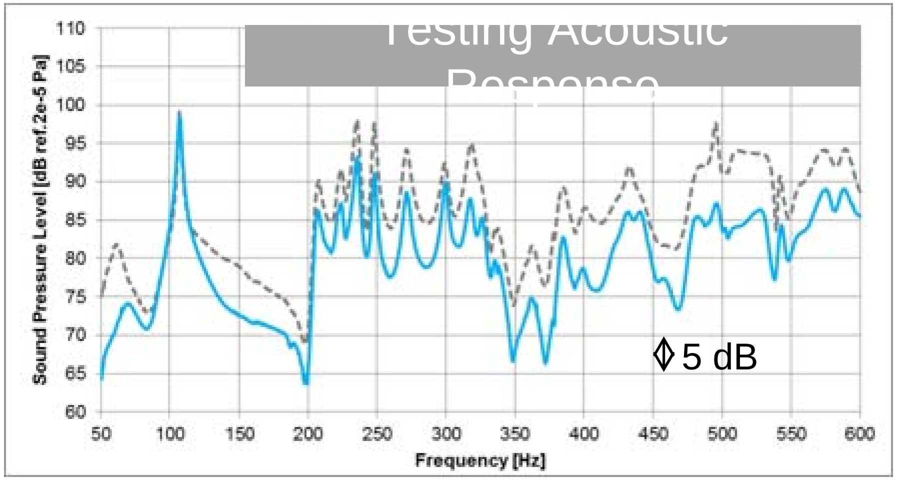
There is not always a direct proportion between mobility and SPL → the transmissibility of the trim is a key factor.

Optimization: Panel stiffening (damping and stiffening) and poro-elastic trim Validation

D
- Nero Acoustics
- 122/200 3.6 kg/m^2
- 122/200 4.2 kg/m^2

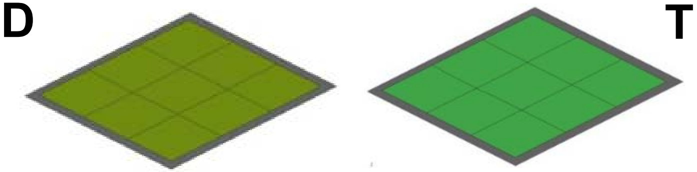
T
- Foam 22 mm +Heavy Layer 2.5 mm
- Foam 22 mm +Felt 3 mm
- Foam 10 mm +Felt 15 mm
- Foam 16 mm +Felt 9 mm





Reference

D

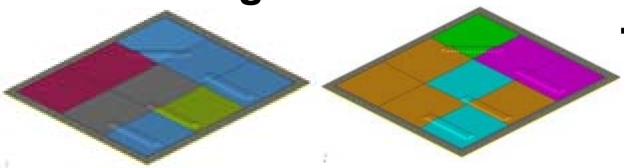


T

Weight 3.5 kg
2.1. kg NCT + 1.4 kg damping

Opt. with an Acoustic Target

D

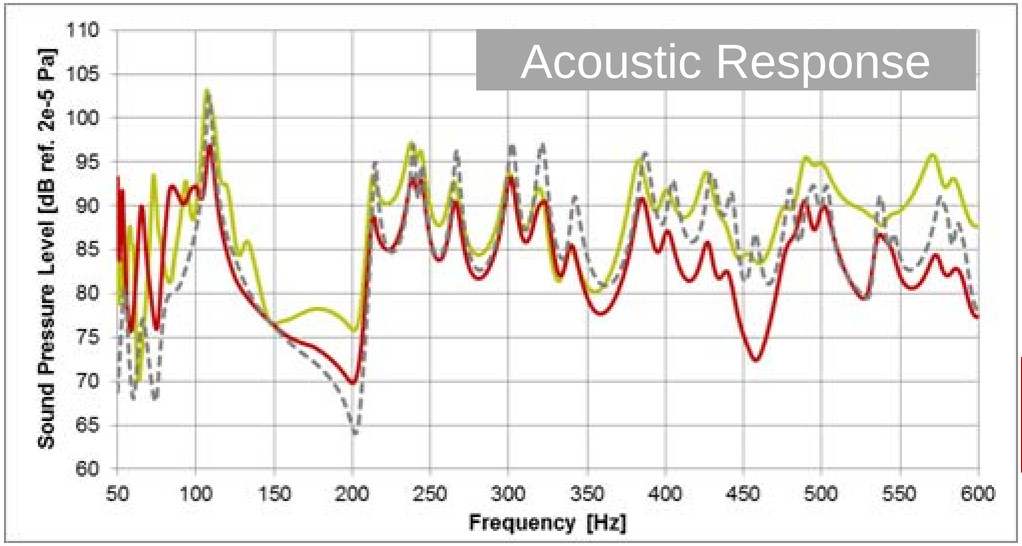


T

Weight 4.25 kg
2.77 kg NCT + 1.48 kg damping

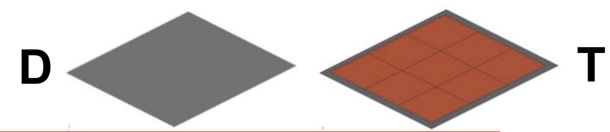
Testing results confirm the performance improvements achieved by the optimization

Further Application:
Optimization only of the poro-elastic trim



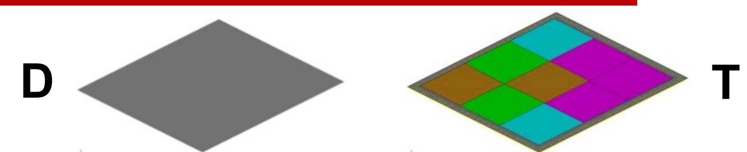
Reference

Weight **4.1 kg**



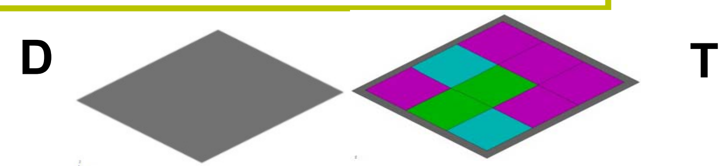
Opt. ONLY trim with an Acoustic Target

Weight **2.3 kg**



Opt. ONLY trim with an Acoustic Target –
NO FOAM+HL AMONG THE VARIABLES
ONLY DSL FELT as TOP LAYER

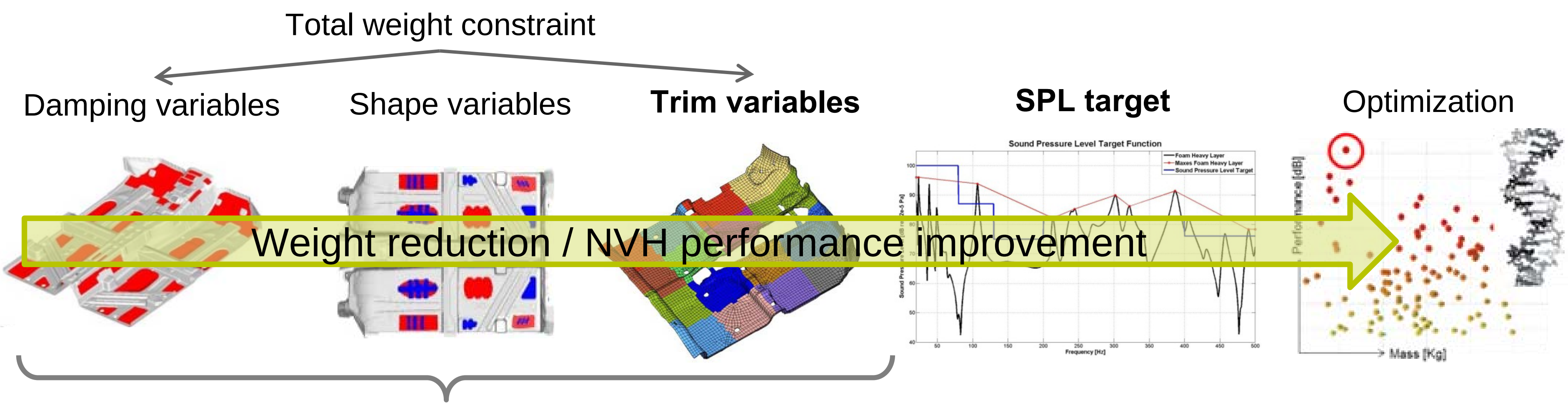
Weight **1.7 kg**



The results of GOLDTRIM indicate how a “Hybrid” trim solution (optimized combination of different compression set) can dramatically drop the weight for an equal structure borne noise performance.

Next Steps

- ✓ The simulation methodology is directly applicable to 3D trim component and full vehicle body modelling
- ✓ We are on the way to apply it on a vehicle for CAE application demonstration for early phase vehicle development.



THANK YOU FOR YOUR ATTENTION

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