CONCEPTUAL CAR DESIGN AT BMW WITH FOCUS ON NVH PERFORMANCE

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Contents

- **IABG company presentation**
- State of the art optimization process for NVH performance
- New approach with Ansa & Optimus
- Summary and conclusion

IABG is a leading European technology enterprise with the core competencies of analysis, simulation & testing as well as plant operation (safety & security)

87.4 %
SCHWARZ Holding GmbH

12.6 % IABG
Mitarbeiterbeteiligungs AG

IABG

Total operating performance: about € 127 million* - Staff: approx. 1000

(about 10% thereof investments in research and development, facilities, HR development)

Automotive	InfoCom	Mobility, Energy & Environment	Aeronautics	Space	Defence & Security
					
Employees: about 120 Development and operation of mechatronic test systems for OEM & suppliers	**Employees:** about 130 Development and operation of secure ICT systems	**Employees:** about 100 Environmental solutions, protection, electro-mobility and change in energy policy.	**Employees:** about 160 Fatigue strength tests for complete airframes and components	**Employees:** about 130 Operation of ESA coordinated Space Test Centres in Ottobrunn and Noordwijk	**Employees:** about 370 Operation of military simulation & test systems for analyses and conceptions

** Business Year 2012*

Mobility & Energy

Wind energy

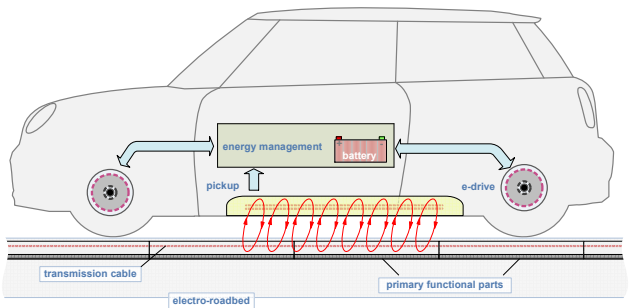
- Site evaluation
- Engineering, modelling and simulation
- Design methods, material analyses
- Design and operation of test stands
- Maintenance and technical diagnostics

Electro-mobility

- Qualification and functional safety of alternative drive systems and vehicles
- Test tracks for inductive in-drive energy transmission

Avoiding idle energy

- Transformation of idle wind energy into methane gas (in planning)

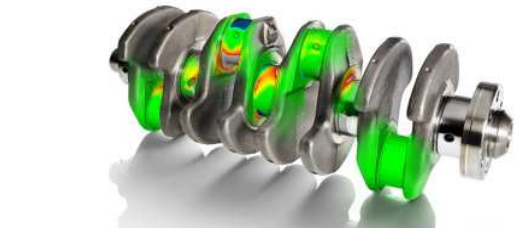


Automotive

Analysis & conception
- Experimental investigations
- **CAE services**
- Mechatronics system analyses

Implementation
- Customer-specific test facilities
- Durability test stands
- System test facilities with hardware-in-the-loop option

Operation
- IABG test centre in Ottobrunn
- On-site test facilities with customers
- Customer-specific investment and operator models (chassis / bodywork / drive)



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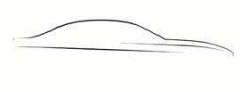
Development cycle



Concept phase | Development phase | Series development phase

MBS/FEM simulation

Hybrid modelling (assembly and substructuring)

Prototypes and concept cars

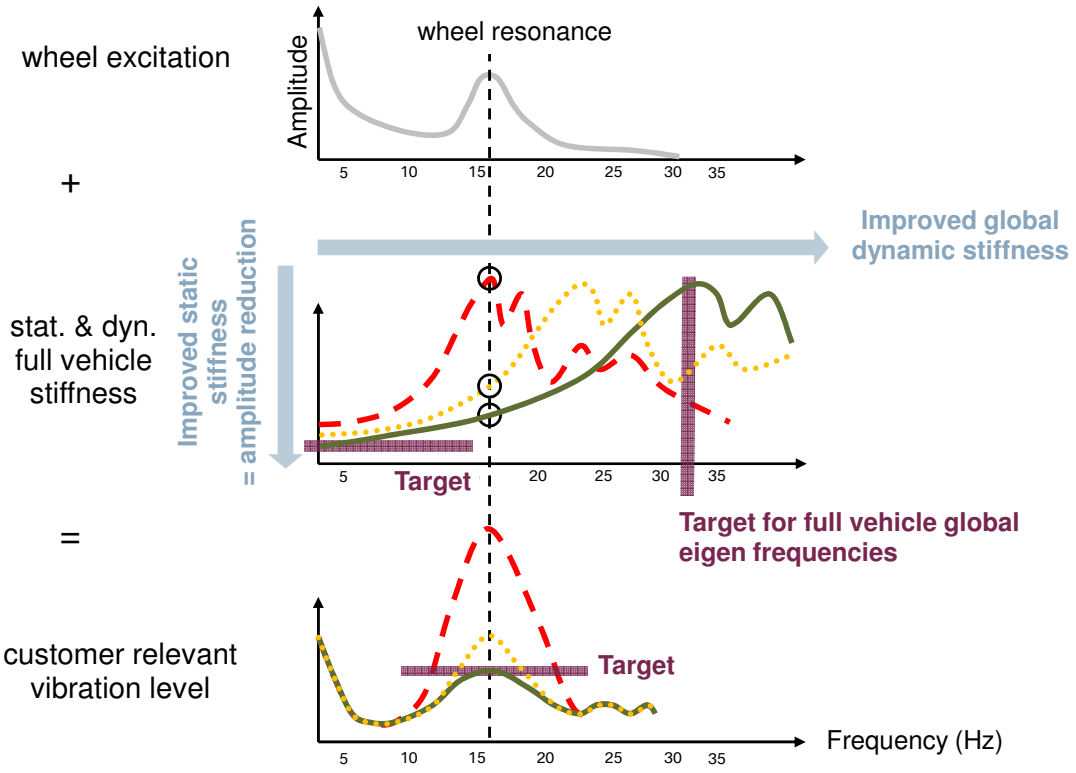
Testing (modal analysis, 4-poster, chassis dyno, mobile testing ...)

Design right first time with less hardware! Virtual prototyping!

Concept optimization

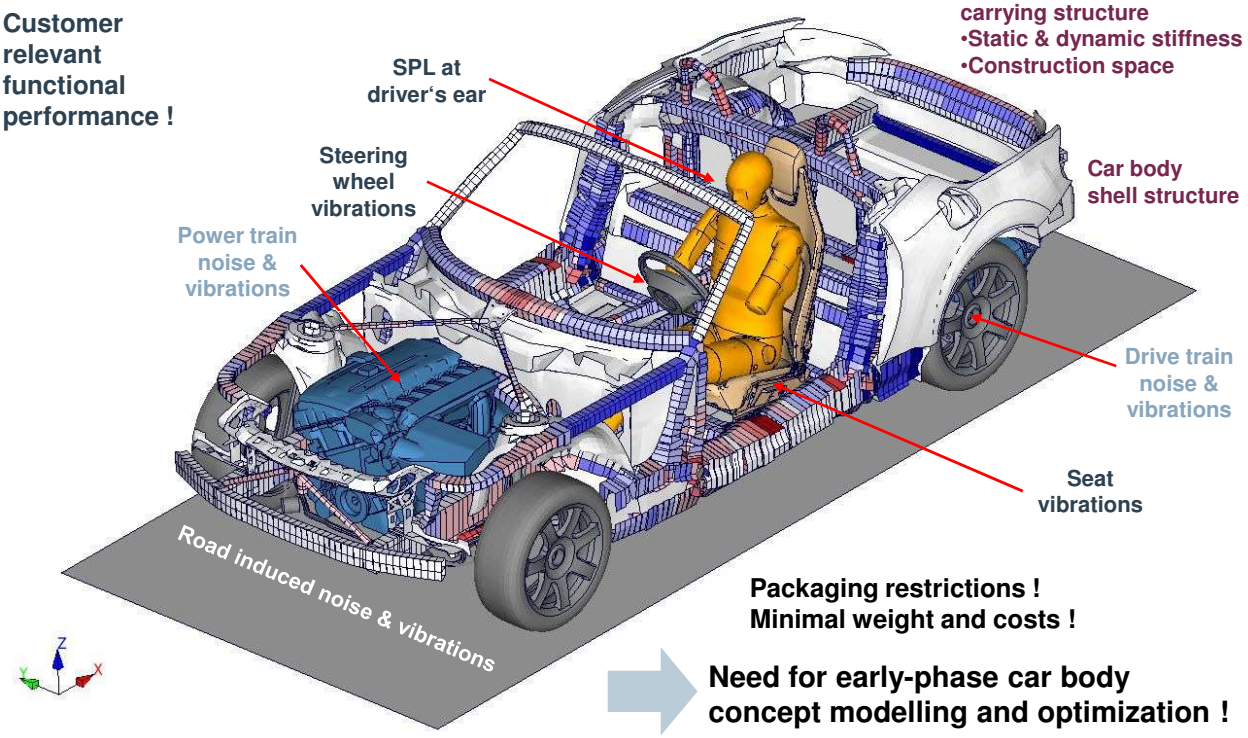
Since 2004 **IABG** supports **BMW** in terms of FE concept modeling with **Beams and Shells FE concept models**

Role of structural dynamics



Car body as NVH ‚backbone‘

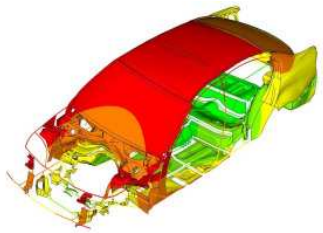
Customer relevant functional performance !



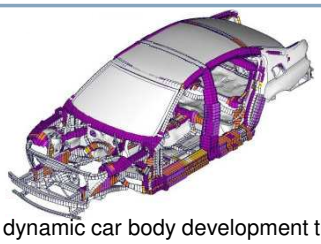
Packaging restrictions !
Minimal weight and costs !

Need for early-phase car body concept modelling and optimization !

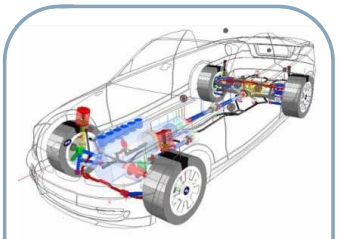
Beams & Shells concept modelling



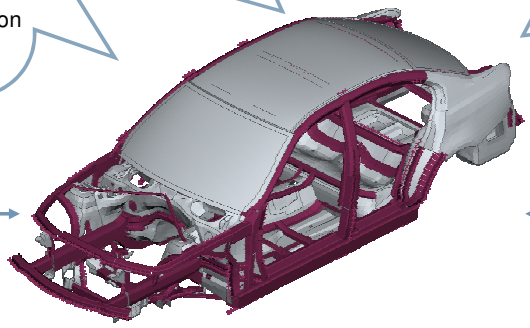
Static and dyn. car body stiffness:
- global static load cases
- local dyn. stiffness at connection points
- car body eigenfrequencies



Structural dynamic car body development through **numerical beam structure optimization**



condensed flexible car body models for full vehicle multi-body vibration comfort simulation

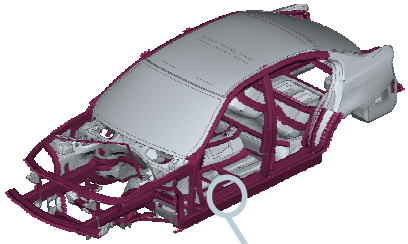


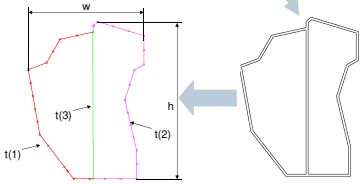
- Beam properties defined with circa 500 different cross sections
- Complete B&S FE model < 50000 nodes (FE fine Model: circa 2.0 million nodes)

- NVH car body target setting
- Early-phase functional development, evaluation and optimization of the car body regarding acoustic and vibration comfort requirements

Optimization process

1500 Design Variables → 25 Load Cases → Numerical Optimization with Nastran SOL 200





Nastran Desvars:
w, h, t(1)…t(3)

Dynamic Stiffness

Static Stiffness

Steering Wheel

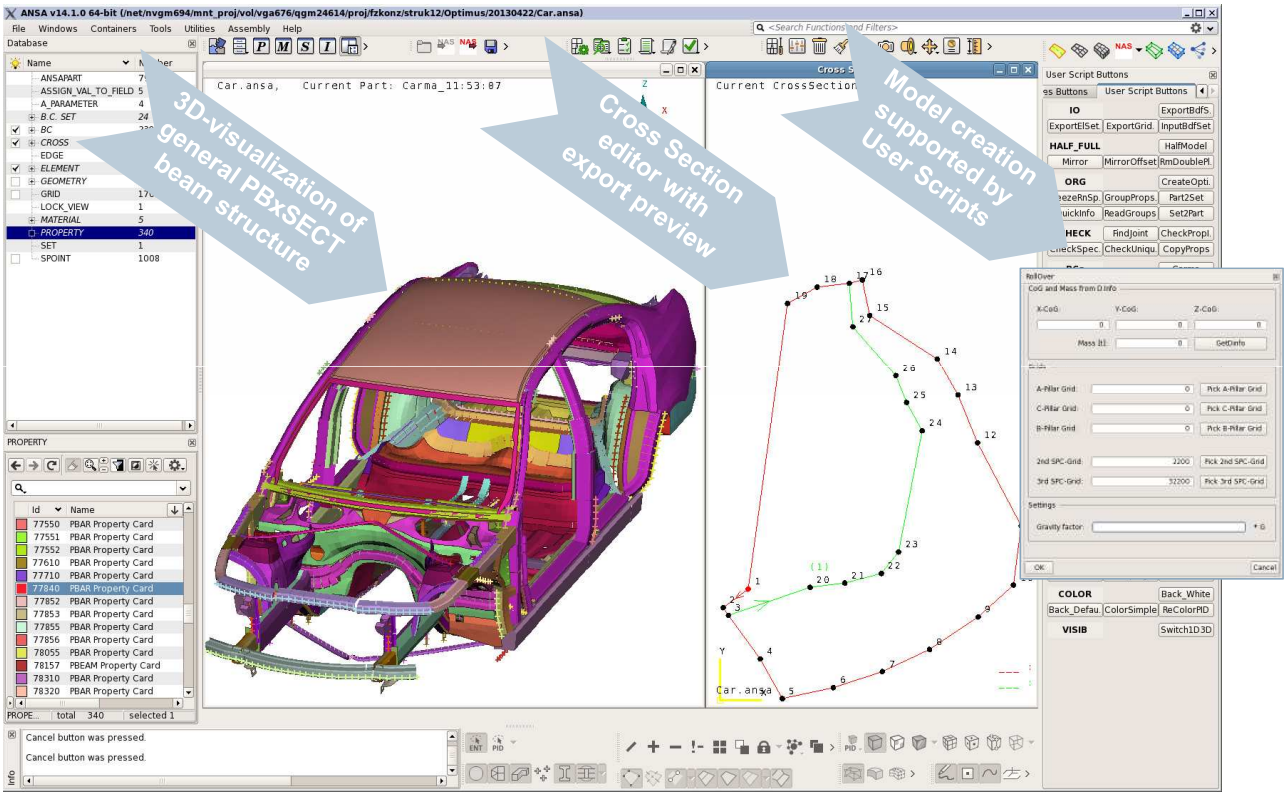
Roll Over

Crash

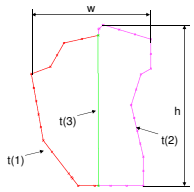
Functional Targets

Minimum Weight

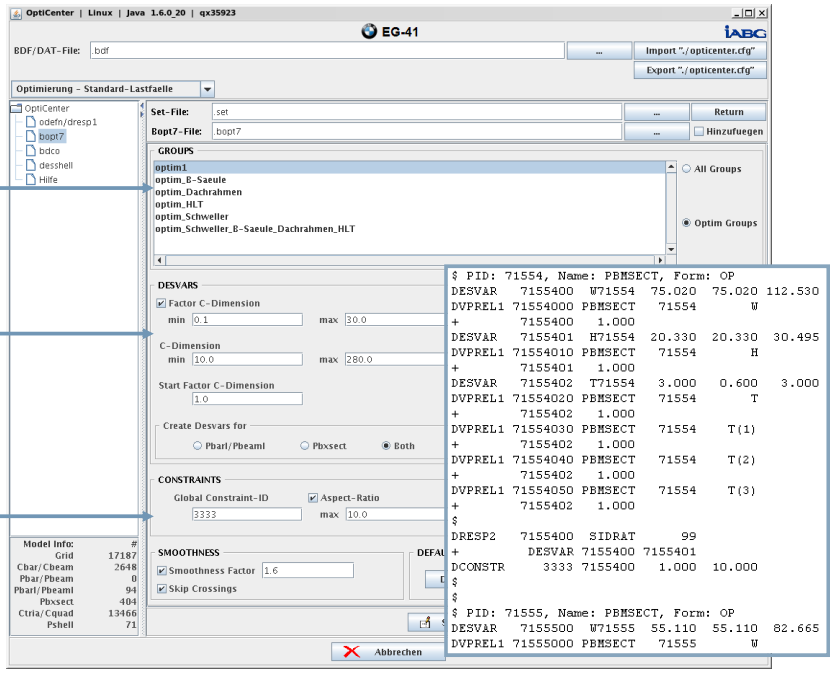
Pre-processing of Beams & Shells concept models with Ansa



OptiCenter: Massive creation of desvars, geometrical responses and geometrical constraints

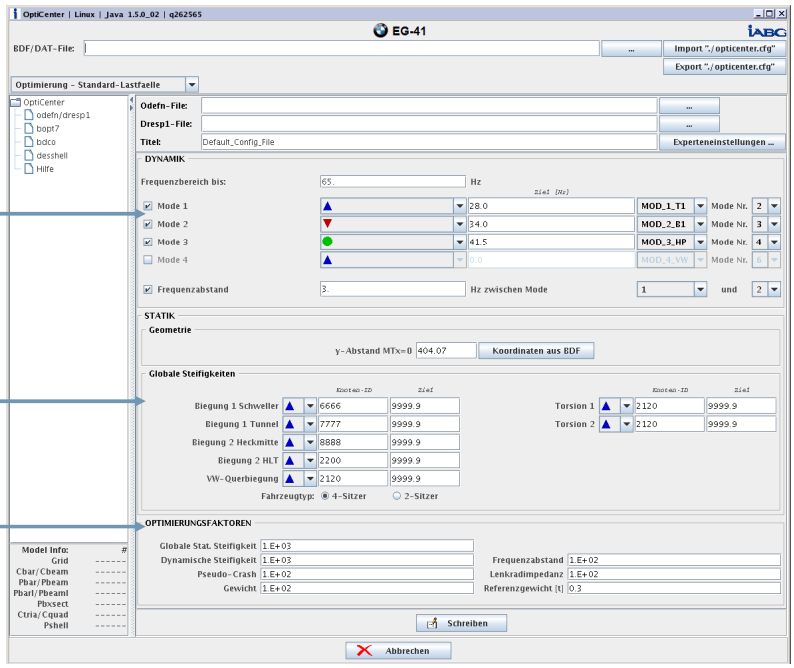


- Application region
- Desvars for outer dimensions and wall thicknesses
- Geometrical responses and constraints



OptiCenter: Creation of functional responses, constraints and objective function

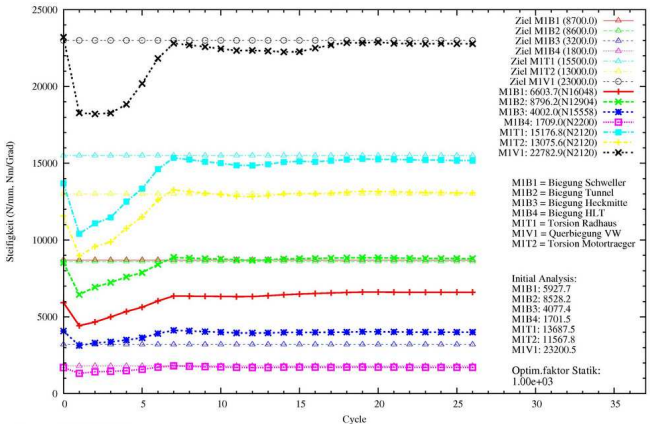
- Responses and constraints for dynamic stiffnesses
- Responses and constraints for static stiffnesses
- Weighting factors

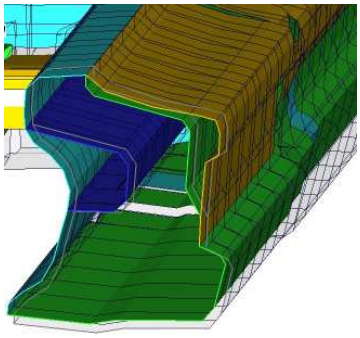


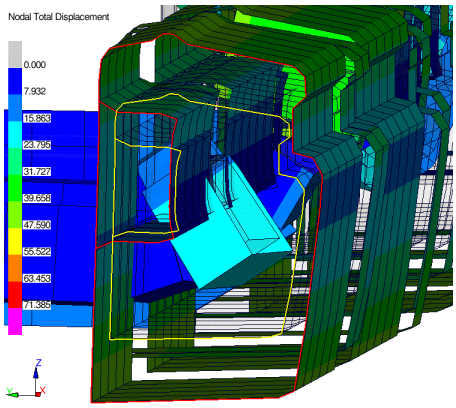
PostProcessing: visualization of optimization results

- Optimization history
- Changes in wall thickness
- Change in construction space

Well established workflow from pre- to post-processing with Ansa, Nastran and proprietary software !







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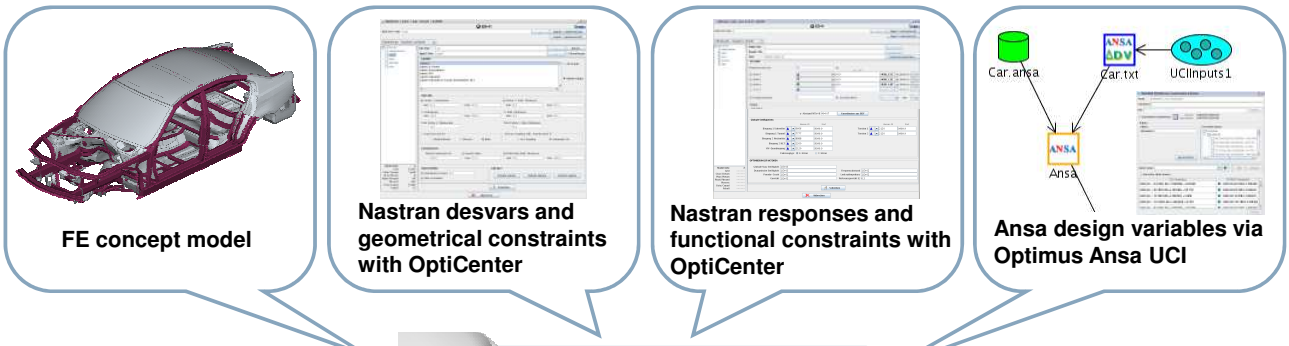
New approach with Ansa & Optimus

- Motivation
  - Use of new optimization algorithms, as an **alternative for the standard Nastran SOL200** gradient-based optimization scheme, in search of the **global optimum**!
  - Investigate **new designs** beyond the variables provided by Nastran SOL200
  - Full vehicle **multi-disciplinary multi-objective optimization**
  - …

New approach with Ansa & Optimus

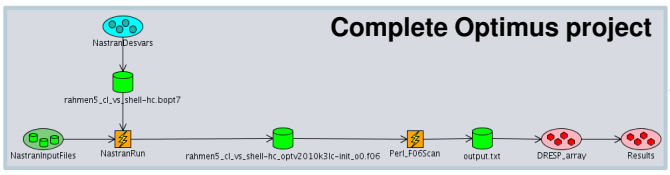


- **Substitution of Nastran design variables** by **Optimus** variables

Optimus Python API

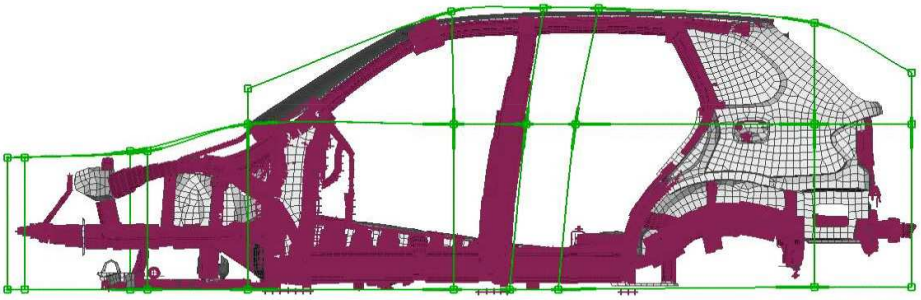
```
optimus
t = optimus.createProject("")
= project.createGraph("Graph1") # a
= project.createGraph("Graph2")
project.numberGraphs() # 3 because a
>>> print project.getProjectDir()
./Project1.optdir/
>>> print project.getRootDir()
./
>>> optimus.saveProject("project1.opt", False)
```

- **Substitution of Nastran responses and constraints** by **Optimus** responses and constraints
- Proprietary programs for **results extraction from f06-file** and mode tracking
- Results created with Optimus formulas



New approach with Ansa & Optimus
Application case: stiffness vs wheel base

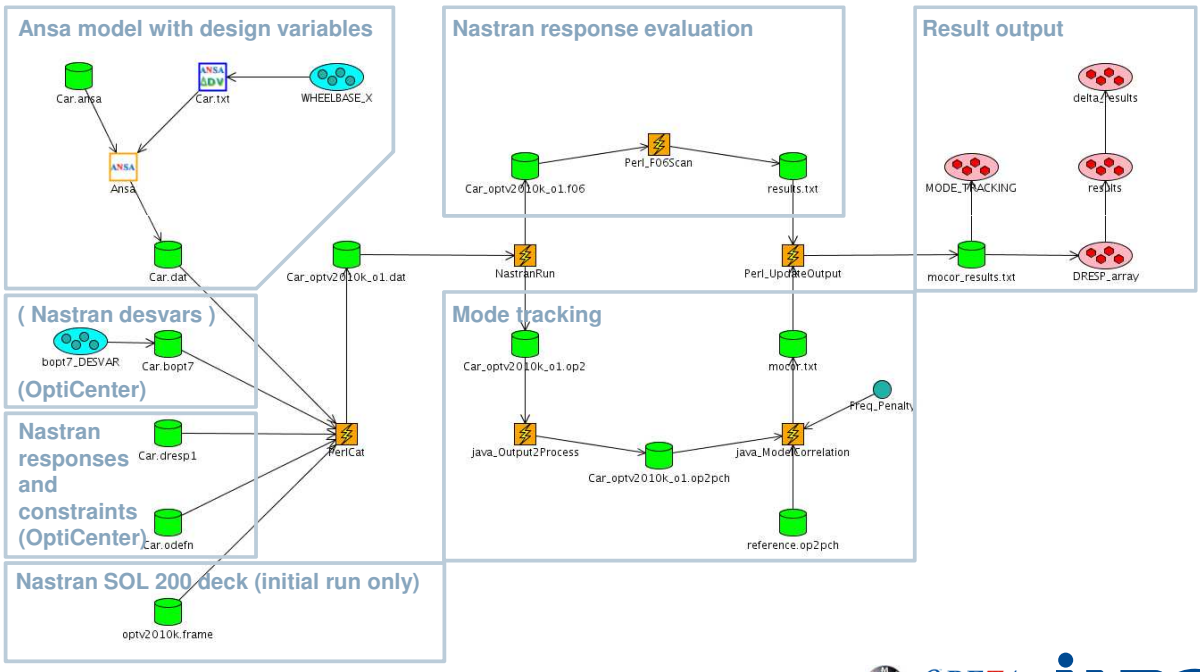
- Question:
  How does the global car body stiffness change with increasing wheel base ?



Parameter study using Optimus, monitoring both global static and dynamic stiffness (eigenfrequencies) !

New approach with Ansa & Optimus
Application case: stiffness vs wheel base

- Optimus workflow (**created by script** using **Optimus Python API**)



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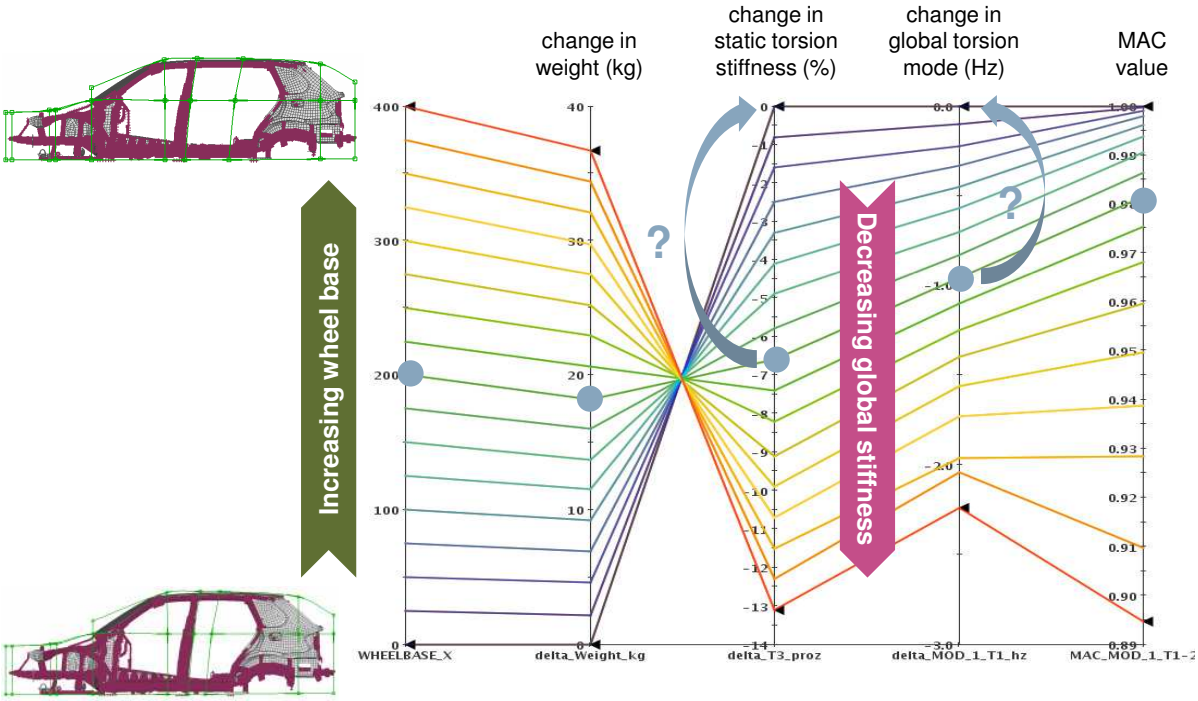
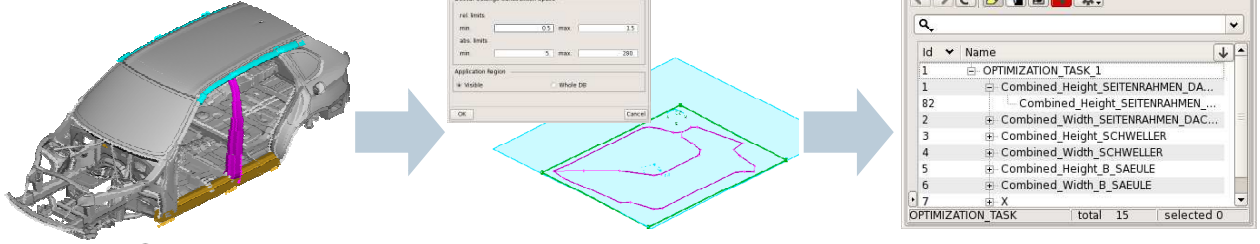
Application case: stiffness vs wheel base



New approach with Ansa & Optimus
Application case: stiffness vs wheel base

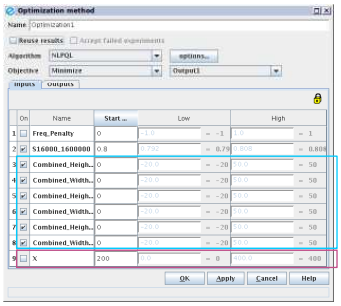
- Realization of **construction space optimization** with Ansa & Optimus with Ansa User Script (mainly provided by BetaCAE) that creates
  - **Morphing boxes** that envelopes every beam cross section
  - Morphing box **parameters for construction space** (width and height of cross section)
  - **Combined parameters** according Ansa part structure
  - **Optimization task**



Optimization run with 200 mm extended wheel base model in order to reach original stiffnesses with combined construction space parameters of **roof carrier**, **b-pillar** and **rocker panel** as desvars

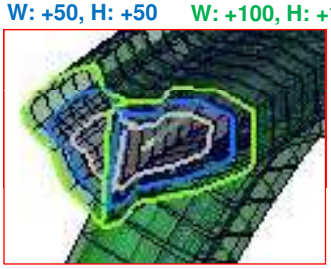
New approach with Ansa & Optimus
Application case: stiffness vs wheel base

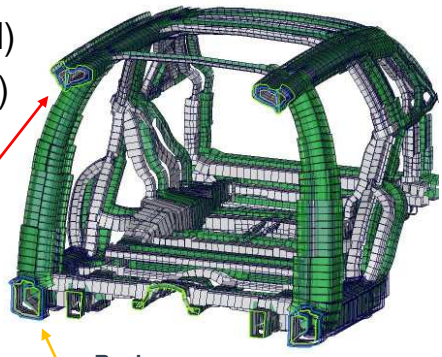
- Optimization method NLPQL (gradient based)
- Scenarios (wheel base param. X = +200 mm)
  - **1:** Width, Height max **+50**, **2:** max **+100** mm



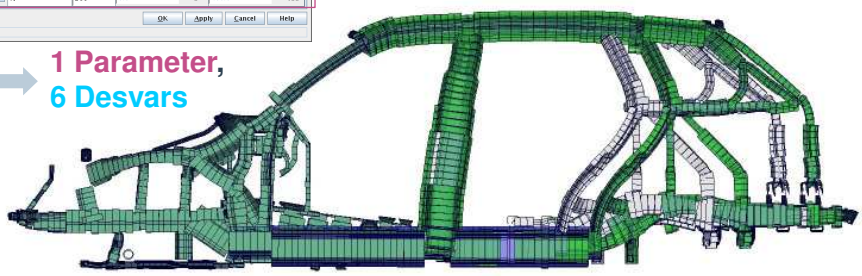
1 Parameter,
6 Desvars

RoofCarrier:
W: +50, H: +50 W: +100, H: +100





Rocker:
W: +50, H: +50 W: +5.2, H: +1.2



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Summary and conclusion

- The Beams & Shells FE concept modelling and optimization process is **well established** at the BMW NVH department and is used extensively in all early phase car development projects for **designing optimal car body structures**.
- **Ansa**, enhanced by various User Scripts, has been established as **"state-of-the-art" pre-processor for PBxSECT models**.
- **Design model creation and post-processing** is done mainly by **proprietary software**
- A new approach is an **automated creation of an Optimus workflow** to have an alternative to gradient-based Nastran SOL200 optimizer

While the very efficient Nastran SOL200 optimizer will probably remain the "workhorse", the new opportunities that come along with **Ansa, Optimus** and **Ansa-Optimus coupling** will be investigated and further developed!

Your contact

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