Methodological development from vehicle concept to modular body structure for the DLR NGC-Urban Modular Vehicle

Methodische Entwicklung vom Fahrzeugkonzept zur modularen Bauweise am DLR NGC-Urban Modular Vehicle

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Agenda

- DLR Institute of Vehicle Concepts, Challenges and motivation for new vehicle concepts and Project Next Generation Car (NGC)
- Holistic development Methodology for vehicle concepts and body structures
- Development of the vehicle body structure for the electric Urban Modular Vehicle
- Prototypical validation of the floor crash concept
- Summary and Outlook

DLR – German Aerospace Center
Institute of Vehicle Concepts:

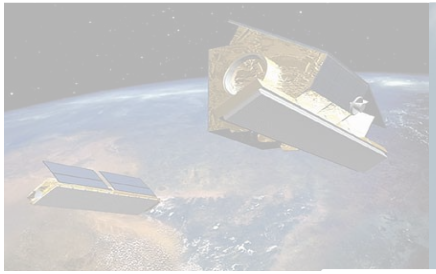
Vehicle systems and technology assessment

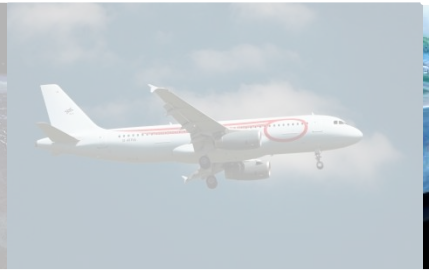
Vehicle energy concepts

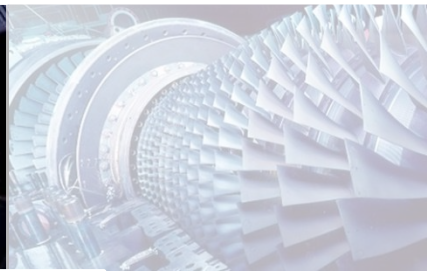
Alternative energy conversion

Lightweight and hybrid construction

SPACE	AERONAUTICS	TRANSPORT	ENERGY



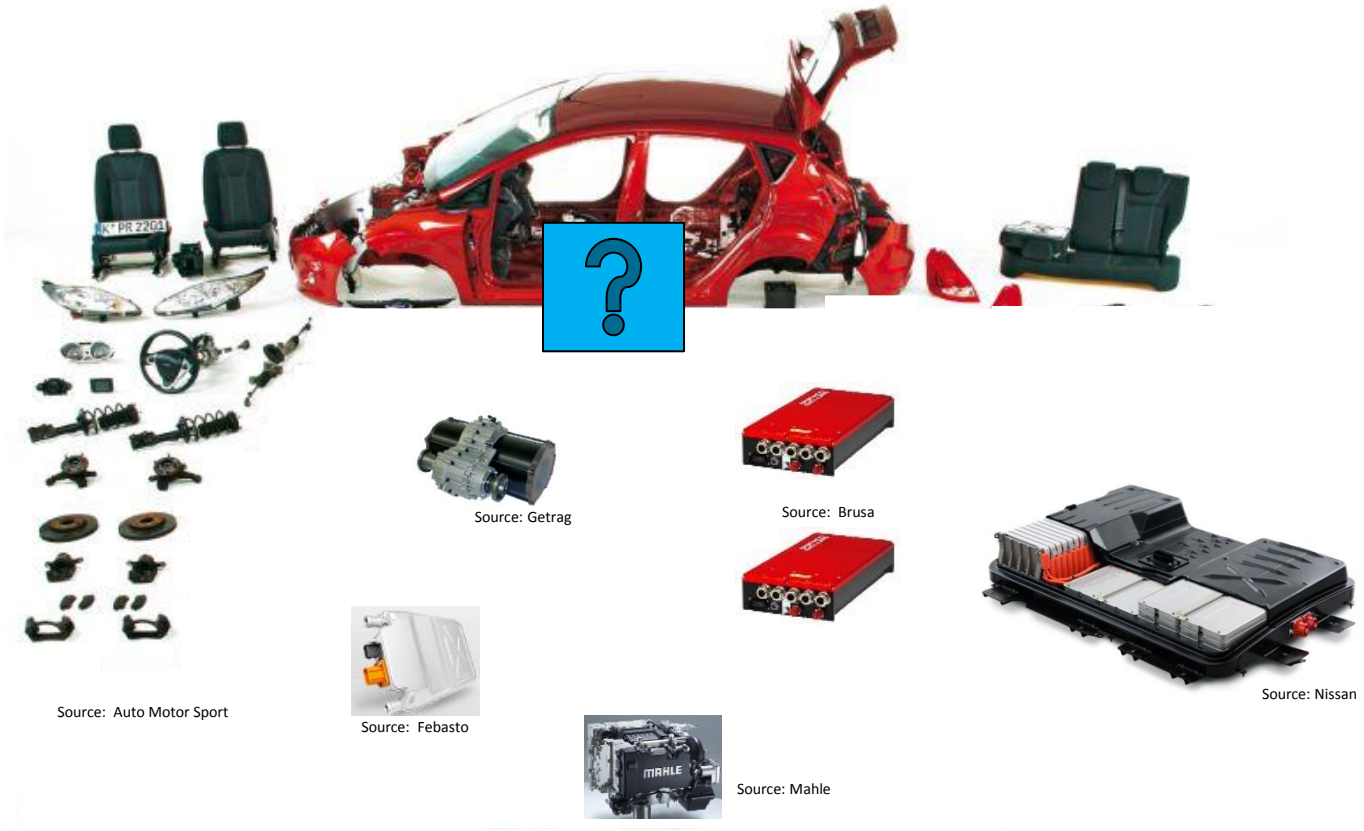




SECURITY

Challenge and motivation

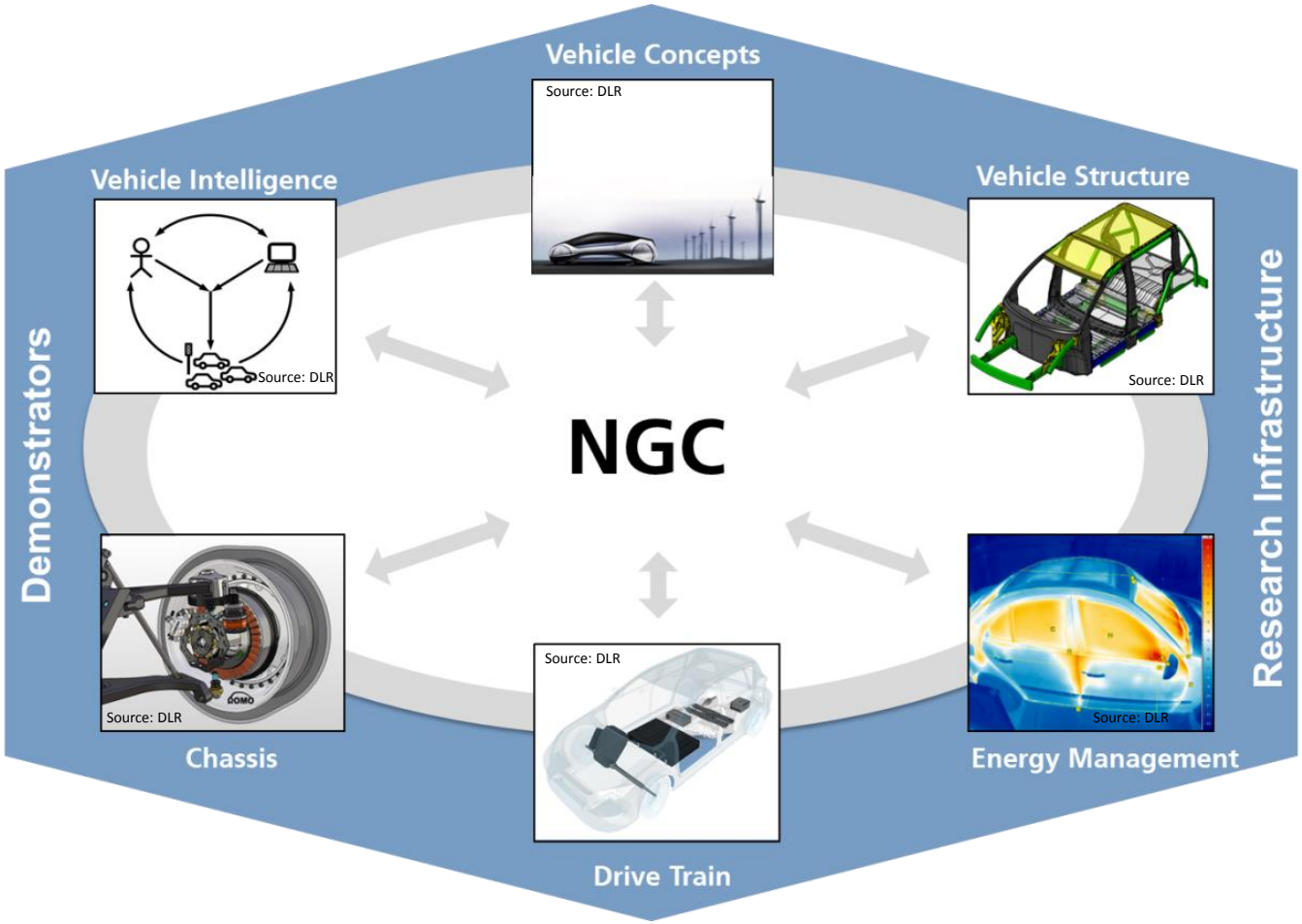
Packaging conventional- and electric vehicle



- remove: combustion engine, exhaust system, transmission …
- add: battery, electric motor, power electronics …

Conclusion → Development of new vehicle concepts, components, BIW

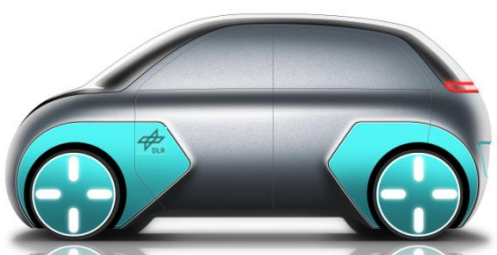
DLR Next Generation Car (NGC)



- Technologies, methods and tools for integrated development of road vehicles of tomorrow

DLR Next Generation Car (NGC) Concepts

Urban Modular Vehicle (UMV)



Electric, intelligent, modular

Interurban Vehicle (IUV)

Comfortable fuel cell vehicle with CFRP body

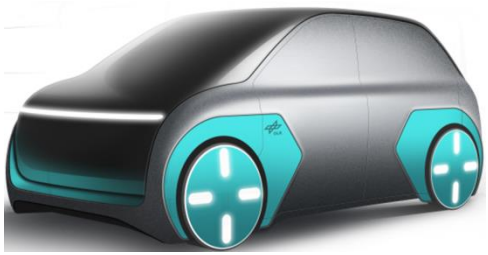
Save Light Regional Vehicle (SLRV)

Cost-effective, very light and safe vehicle, class L7e

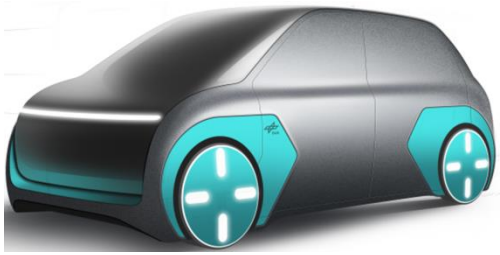
DLR Next Generation Car (NGC)
Concept: Urban Modular Vehicle

- The UMV is a intelligent and safe electric vehicle for urban use area for tomorrow's mobility.
- An example of the modularity of the UMV is the possibility of different derivatives on one modular system:

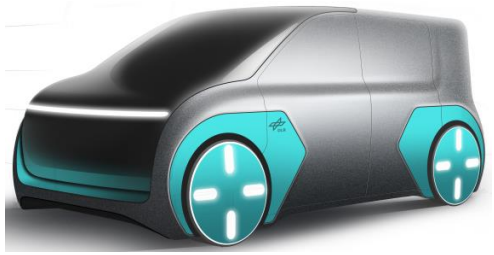
UMV Basic



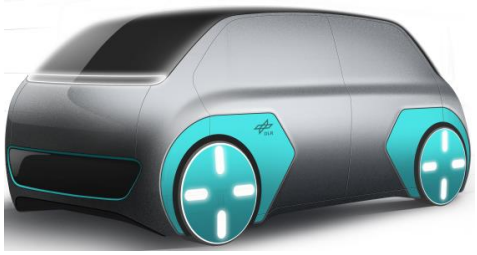
UMV Long



UMV Cargo



UMV Peoplemover



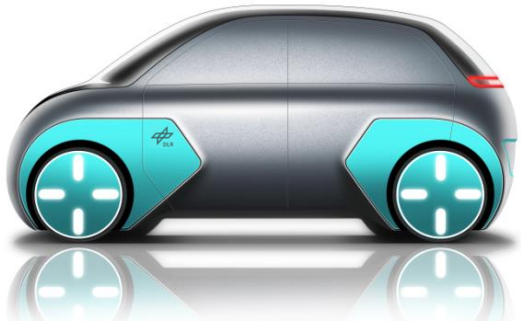
UMV Cargomover

DLR Next Generation Car (NGC)
Concept Highlights: Urban Modular Vehicle

Vehicle Intelligence
- Several levels of automation, assist to fully automated and driverless selectable
- 360° environment detection, C2X-networking
- Cooperation with the traffic
- …

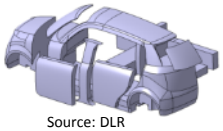

Source: DLR

Vehicle Concepts
- Urban compact concept, intelligent, light and save
- …



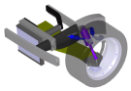
Source: DLR

Vehicle Structure
- Vehicle empty weight 680 kg
- Optimized structures specifically for battery-electric vehicle in the sense of purpose design
- …



Source: DLR

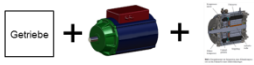
Chassis
- Modular, mechatronic, integrated lightweight chassis with innovative materials
- Steer-by-Wire-; Brake-by-wire,
- …



Source: DLR

Source: DLR

Drive Train
- The modular electric drive with 2 x 25 kW for the basic model, with high speed spreading on the rear axle
- PCM-energy storage
- …



Source: DLR

Energy Management
- Intelligent overall vehicle energy management
- Connection of heat and mass flows, Cabine-, battery-, electric motor-management
- …

Holistic development Methodology for vehicle concepts and body structures

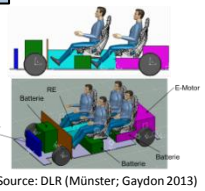
Phase 1: Concept phase

Vehicle concept parameters
(Number of seats, range, Application area …)

Vehicle conception
(geometrically and simulative)

Parametric CAD-vehicle space model
(tunnel, double bottom, B-pillar …)

Source: DLR (Münster; Gaydon 2013)



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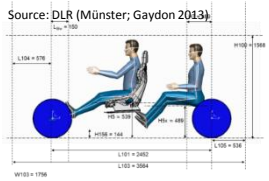

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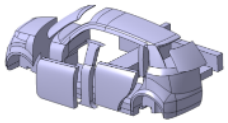

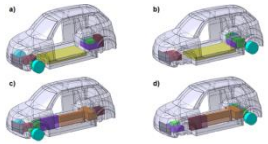

Mobility requirements/
Market/Customer

Vehicle conception
geometrically/simulative

Vehicle dimension/
Package

Design/Parametric CAD-vehicle space model

Package study

Phase 2: Body structure development phase

Holistic development Methodology for vehicle concepts and body structures

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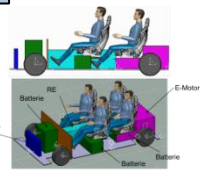

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Vehicle conception
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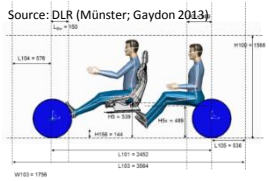
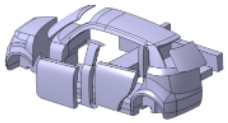


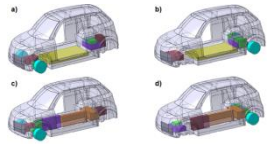
Source: DLR (Münster; Gaydon 2013)

Vehicle dimension/
Package



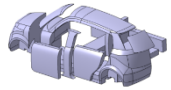
Source: DLR (Münster; Gaydon 2013)

Design/Parametric CAD-
vehicle space model

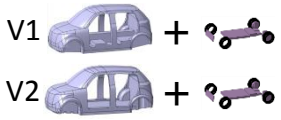


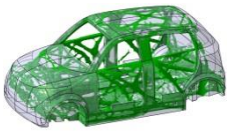
Package study

Phase 2: Body structure development phase

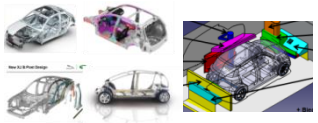


Selection of Basic form variant and package



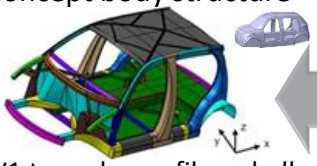


Topology optimization for global load pathfinding

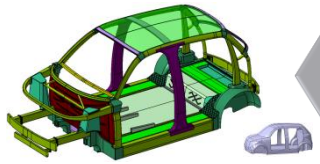


State of the art comparison

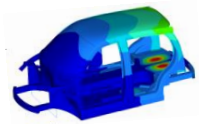
Concept body structure



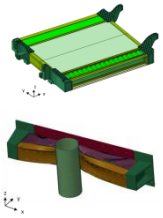
V1 tunnel + profile + shell



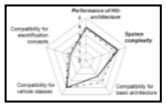
V2 without tunnel + profile + functionally integrated sandwich structures



Material selection, MDO optimization with concept body structure



Prototypical validation



Overall Rating

Concept review | **Component validation** | **Optimization** | **Engineering design** | **Load path analysis**

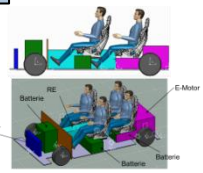
Phase 1: Vehicle concept phase

Phase 1: Concept phase

Vehicle concept parameters
(Number of seats, range, Application area …)

Vehicle conception
(geometrically and simulative)

Parametric CAD-vehicle space model
(tunnel, double bottom, B-pillar …)



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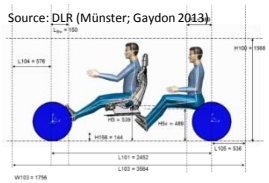

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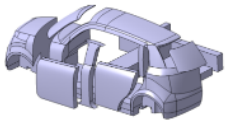

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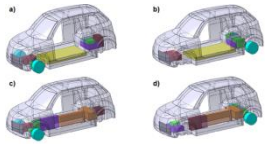


Mobility requirements/
Market/Customer

Vehicle conception
geometrically/simulative

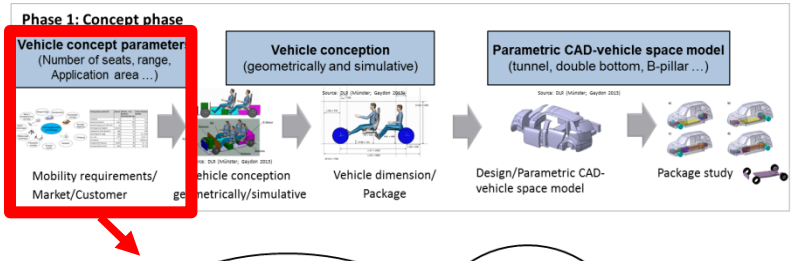
Vehicle dimension/
Package

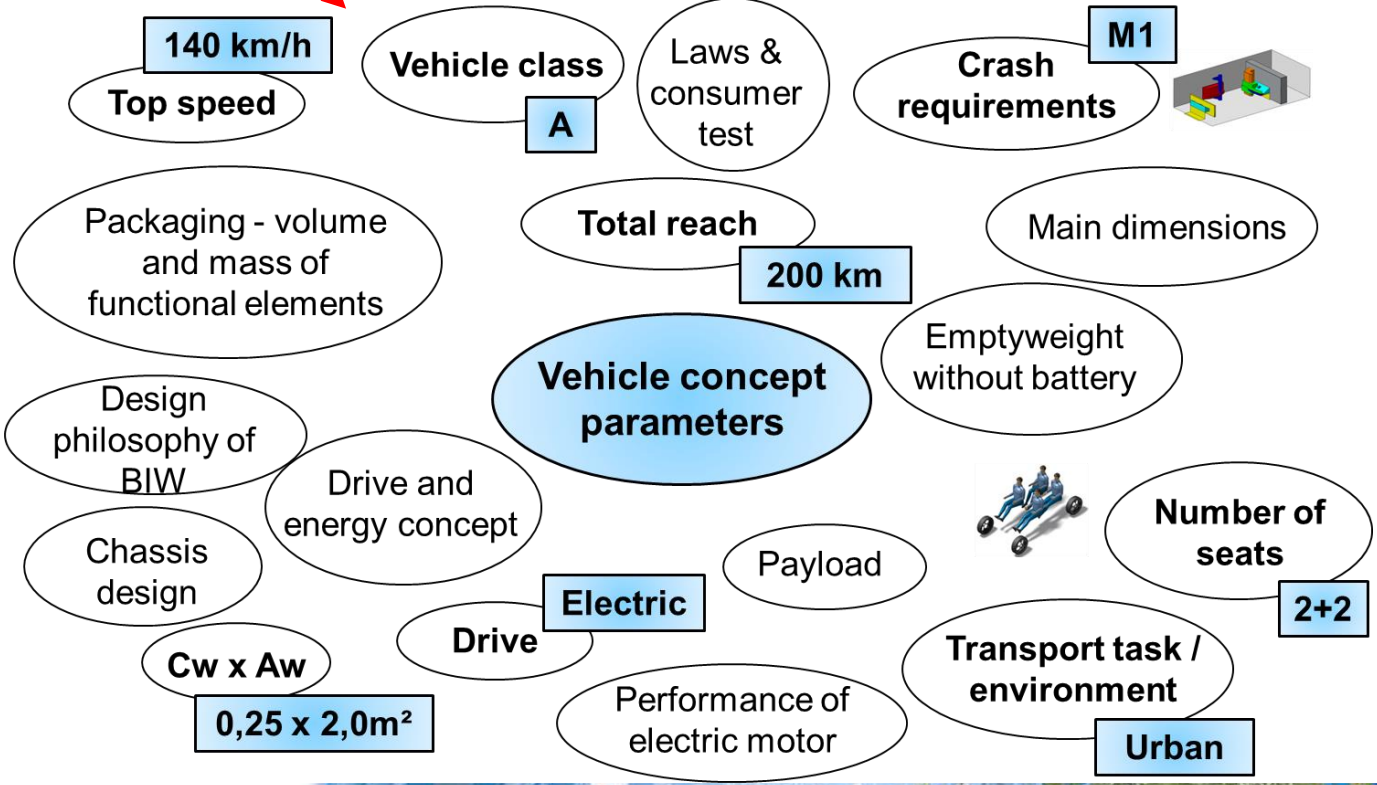
Design/Parametric CAD-
vehicle space model

Package study

Phase 1: Vehicle concept phase

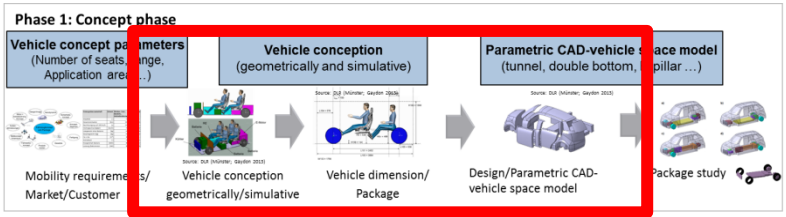
Vehicle concept parameters, first boundary conditions





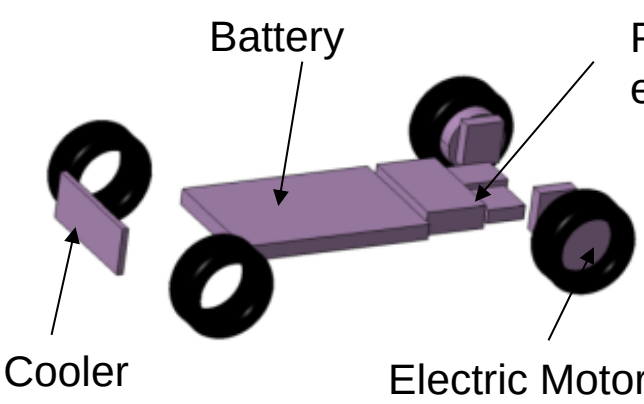
Phase 1: Vehicle concept phase

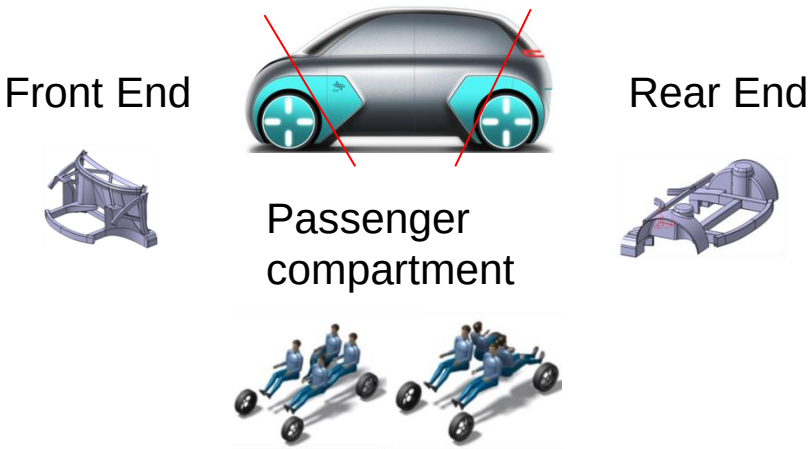
Vehicle conception



Simulative part:
the volume- and mass-intensive components are dimensioned with the aid of the driving resistance equation.

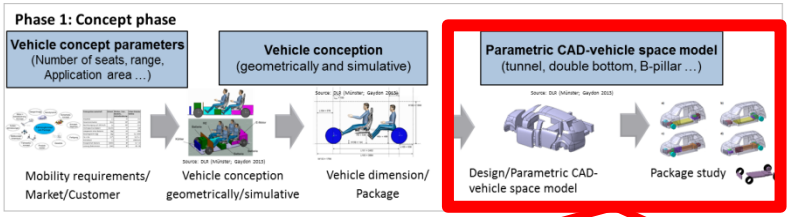
Geometric part:
the dimensions of the passenger compartment and the front/rear of the vehicle are estimated.



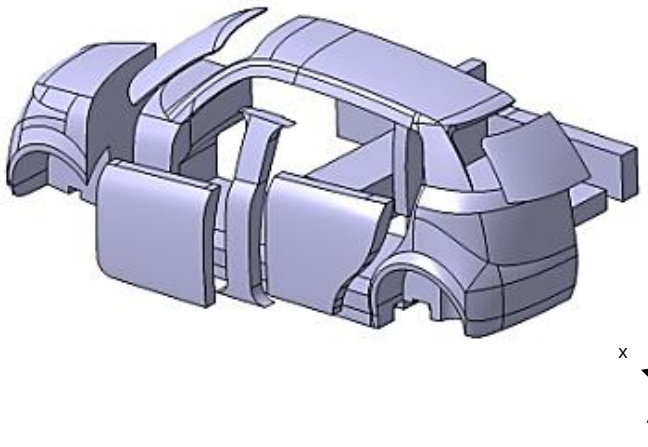


Phase 1: Vehicle concept phase

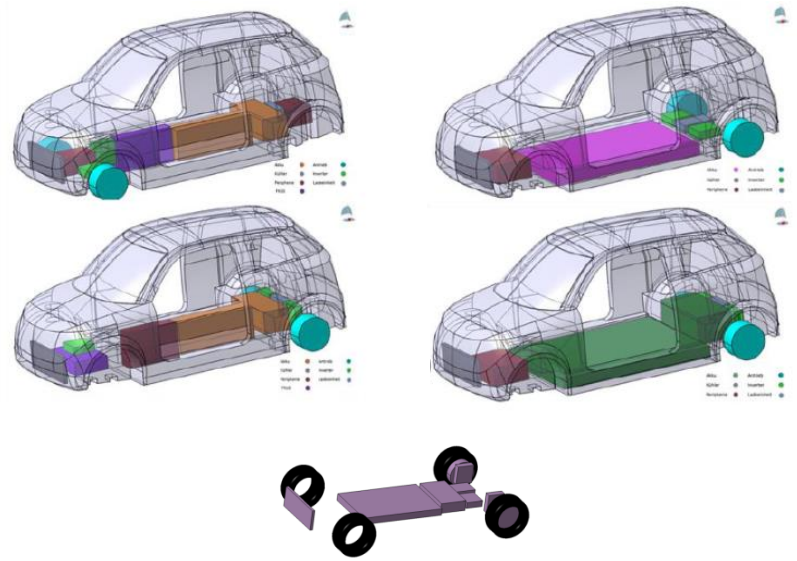
Vehicle CAD-Modell



Parametric CAD-vehicle space model



Analysis and evaluation of different package variants in urban space model



Phase 1: Vehicle concept phase

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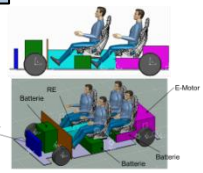
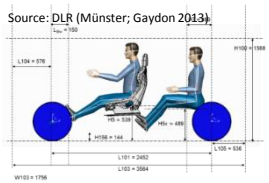
(tunnel, double bottom, B-pillar …)



Source: DLR (Münster; Gaydon 2013)



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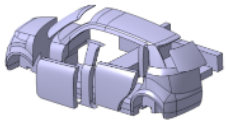

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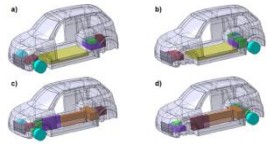

Mobility requirements/
Market/Customer

Vehicle conception
geometrically/simulative

Vehicle dimension/
Package

Design/Parametric CAD-
vehicle space model

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Holistic development Methodology for vehicle concepts and body structures

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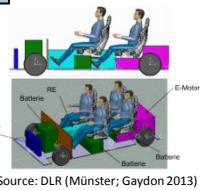

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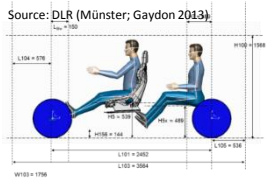

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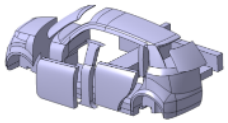
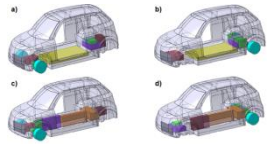
Vehicle dimension/
Package



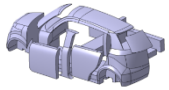
Source: DLR (Münster; Gaydon 2013)

Design/Parametric CAD-
vehicle space model

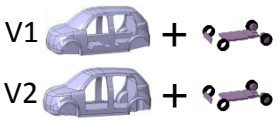


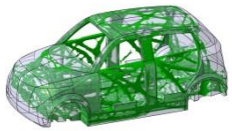
Package study

Phase 2: Body structure development phase

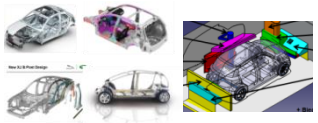


Selection of Basic form variant and package



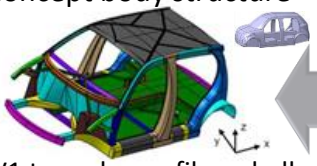


Topology optimization for global load pathfinding

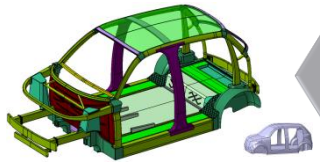


State of the art comparison

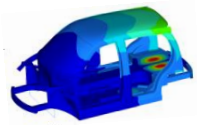
Concept body structure



V1 tunnel + profile + shell

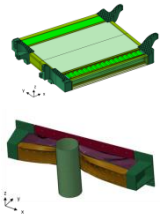


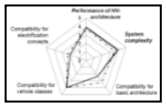
V2 without tunnel + profile + functionally integrated sandwich structures



Material selection, MDO optimization with concept body structure

Prototypical validation



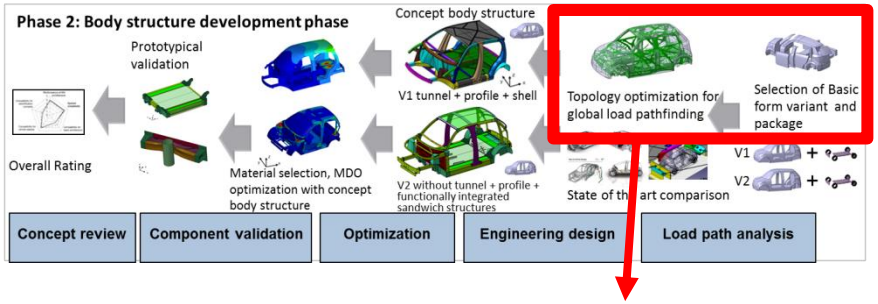


Overall Rating

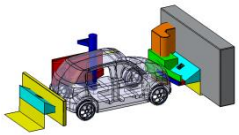
Concept review | **Component validation** | **Optimization** | **Engineering design** | **Load path analysis**

Phase 2: Body structure development phase

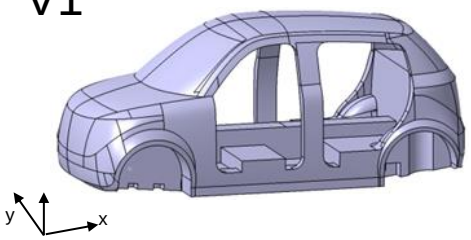
Topology optimization on space model for global load pathfinding

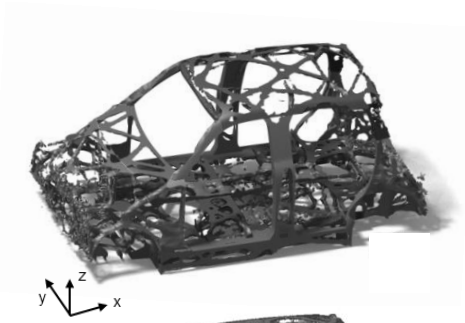


Topology optimization in different space model variants

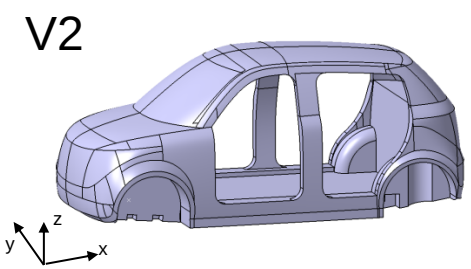


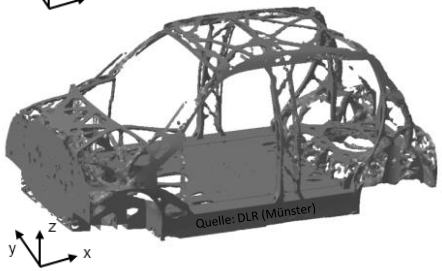
V1





V2

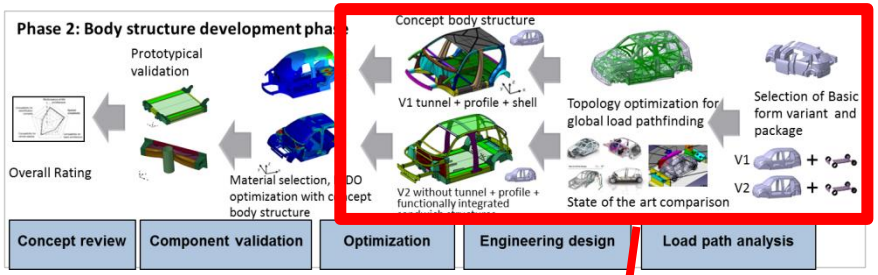




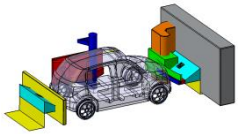
DLR

Phase 2: Body structure development phase

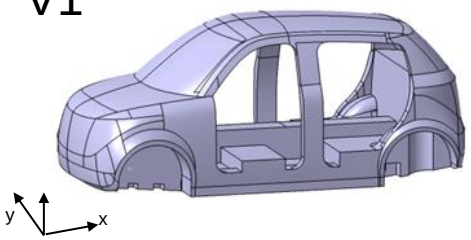
Development of the vehicle body structure

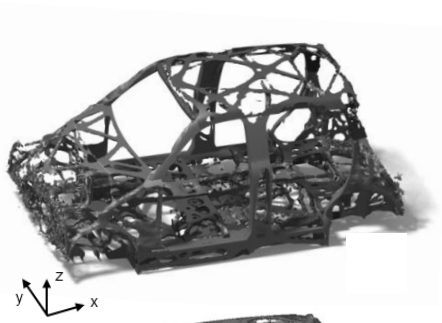


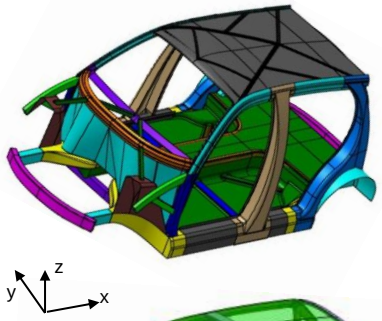
Development of two different vehicle body structures



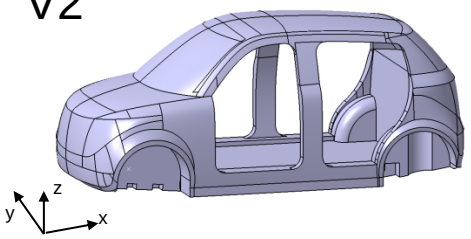
V1

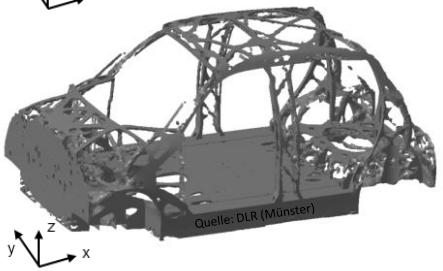


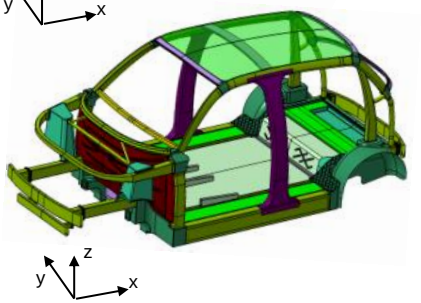




V2

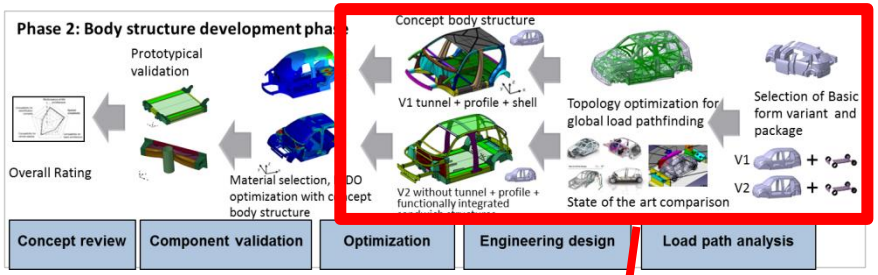




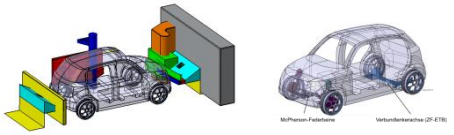


Phase 2: Body structure development phase

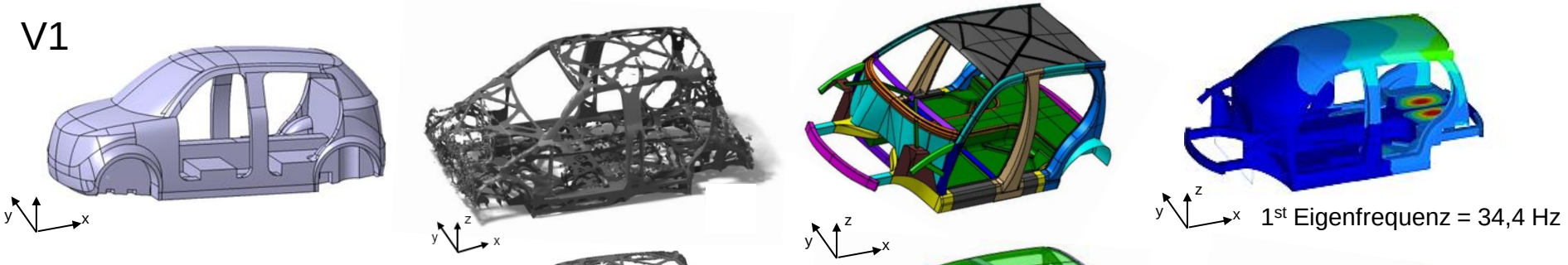
Development of the vehicle body structure



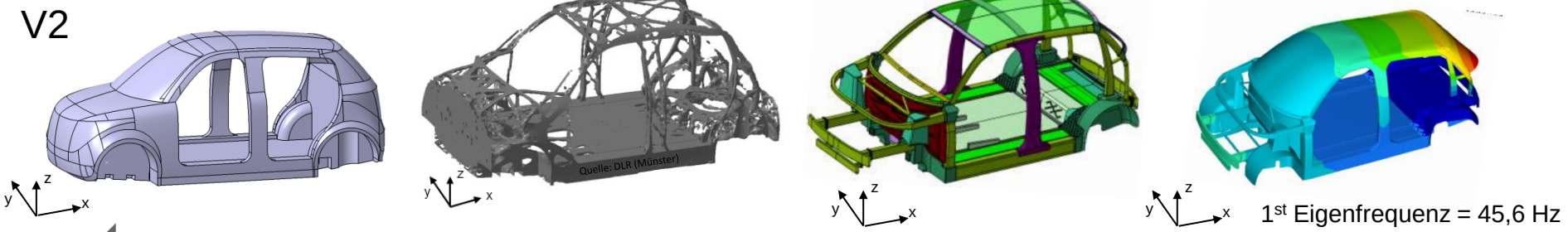
Static analysis of vehicle body structures



V1

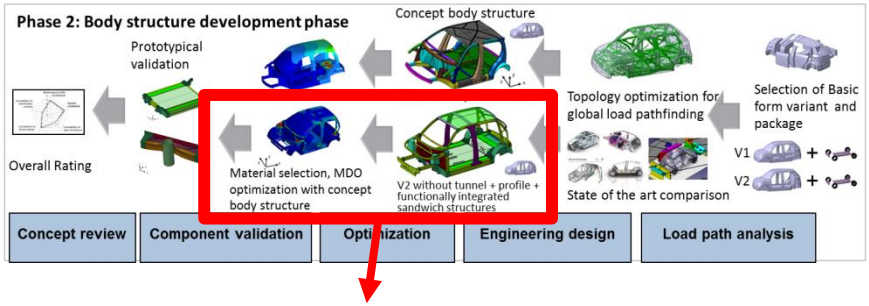


V2



Phase 2: Body structure development phase

Design philosophy



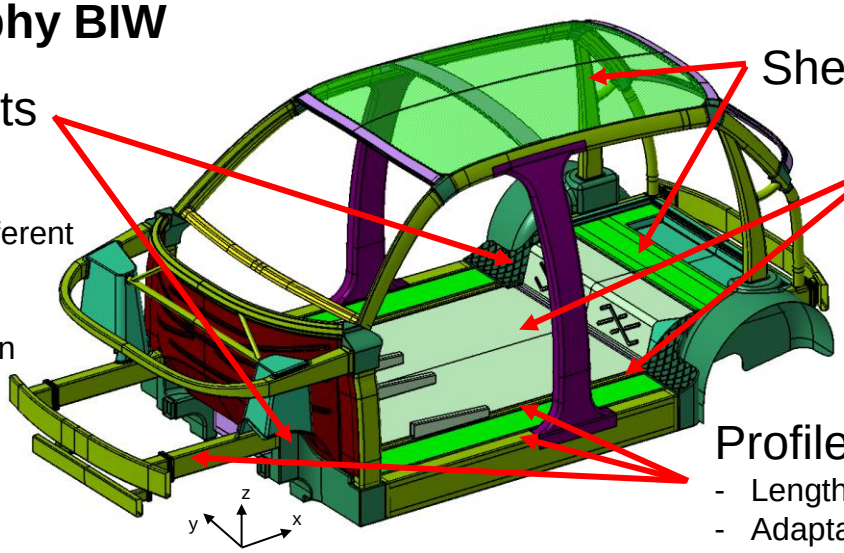
Materials

		RGB colour code
Steels	**Low Strength Steel:** Mild steels	R 153, G 204, B 255
	High Strength Steels (HSS):	R 051, G 102, B 255
	High Strength Interstitial-free Steels (HSIF),	
	Bake Harding Steels (BH), High Strength Low Alloy	
	Advanced High Strength Steels (AHSS):	R 255, G 153, B 204
	Dual Phase Steels (DP),	
	Transformation Induced Plasticity Steels(TRIP)	
	Stainless steels: Austenitic stainless steels	R 051, G 051, B 153
	Ultra High Strength Steels(UHSS):	R 204, G 153, B 255
	Complex Phase Steels(CP),Martensitic Steels(MS)	
	Press Hardened Steels(PHS)	R 128, G 000, B 128
Aluminium	**Aluminium sheets:** 7xxx series	R 051, G 204, B 153
	Aluminium sheets: 6xxx series	R 000, G 255, B 000
	Aluminium sheets: 5xxx series	R 204, G 255, B 204
	Aluminium extrusion profiles	R 153, G 204, B 000
	Cast aluminium	R 051, G 153, B 102
	Magnesium	R 255, G 255, B 000
Plastics	**Fibre reinforced plastics**	R 255, G 000, B 000
	Duroplastics, including Sheet Molding Compound	R 255, G 153, B 000
	Thermoplastics	R 153, G 051, B 000
	Elastomers	R 255, G 204, B 204
	Other materials, namely :PUR RIM	R 192, G 192, B 192

Design philosophy BIW

Node elements

- Cast nodes
- Adaptive node
- Combination of different materials
- modularising
- Function integration



Shear fields

Sandwich plates

- Crash-/Passenger cell area
- Function integration
- loads and functions (for example: air channel)
- modularising

Profiles

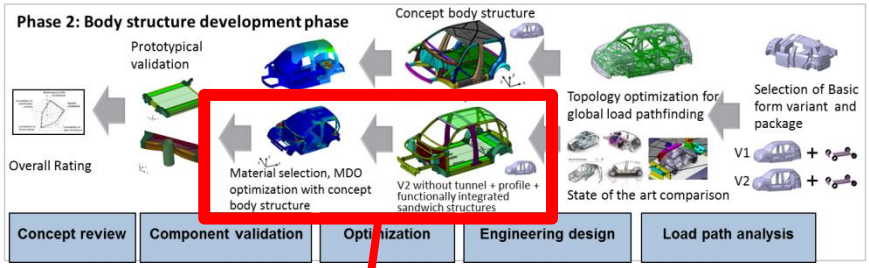
- Length variability
- Adaptability
- Function integration

Aluminum intensive frame structure with profiles and nodes with functionally integrated sandwich surfaces and flat components in FRP

Phase 2: Body structure development phase

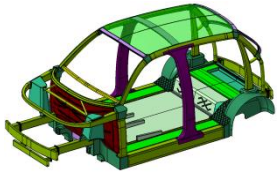
Design philosophy

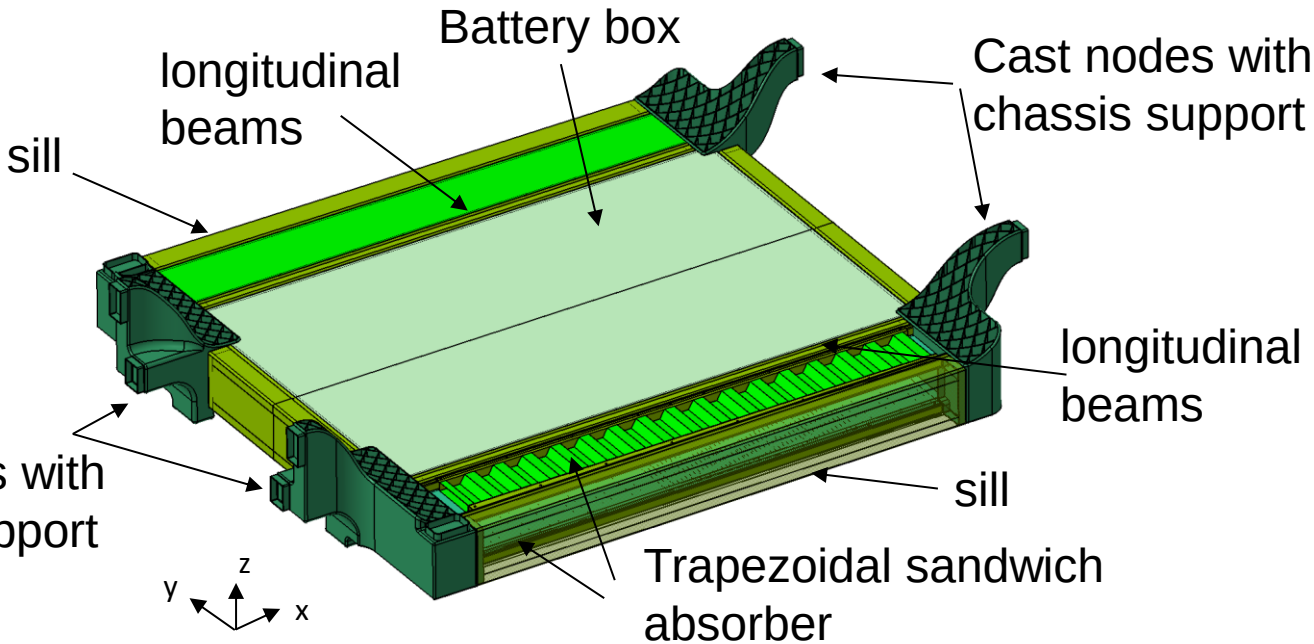
Materials



Aluminium	**Aluminium sheets:** 7xxx series	R 051, G 204, B 153
	Aluminium sheets: 6xxx series	R 000, G 255, B 000
	Aluminium sheets: 5xxx series	R 204, G 255, B 204
	Aluminium extrusion profiles	R 153, G 204, B 000
	Cast aluminium	R 051, G 153, B 102

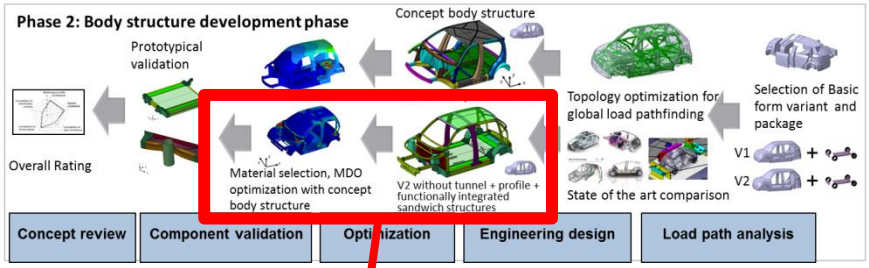
Design philosophy floor concept



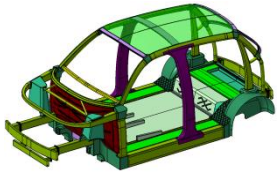


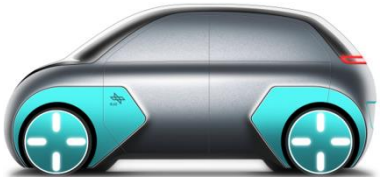
Phase 2: Body structure development phase

Design philosophy

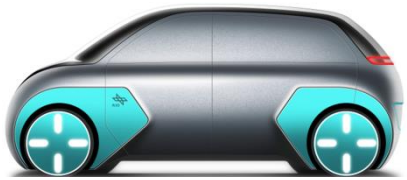


Modularity of the body in white:



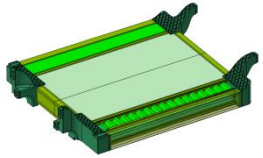


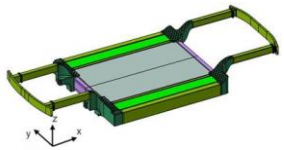
3600 mm

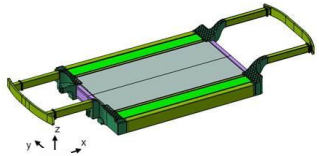


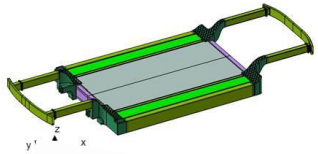
4000 mm

4100 mm





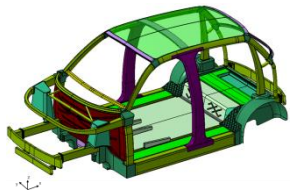


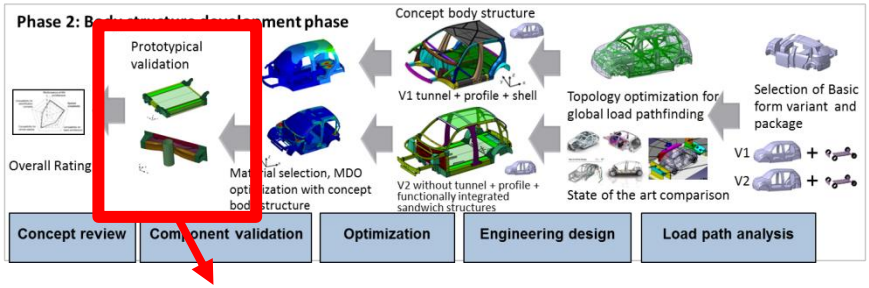


- **Length variability**
- Drive variability
- Chassis variability
- **...**

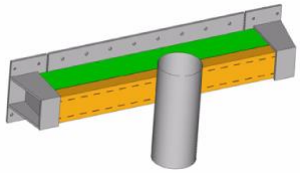
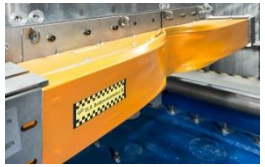
Phase 2: Body structure development phase

Prototypical validation of the floor crash concept



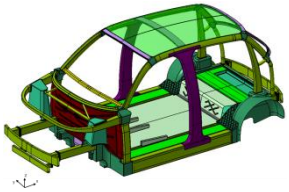


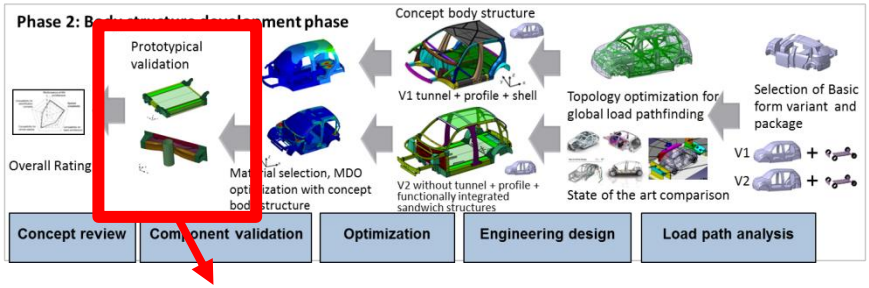
Levels of prototypical validation of the floor crash concept:

	Complete vehicle	Component	Floor crash concept
Simulation			
Experiment			

Phase 2: Body structure development phase

Complete vehicle crash simulation





	Complete vehicle	Component	Floor crash concept
Simulation			
Experiment			

Complete vehicle crash simulation

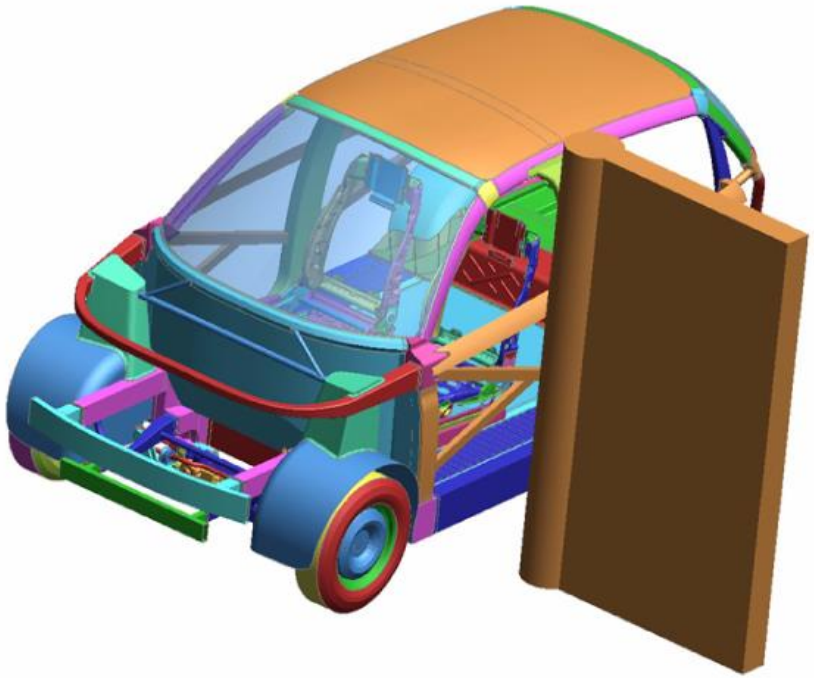
- Vehicle mass 984 kg
- Euro NCAP Pole-crash
- v = 29 km/h

Objectives:

- Dimensioning of the BIW
- Review of the new body concept

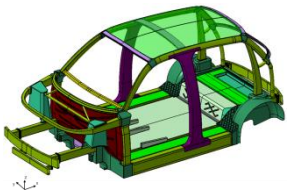
Results:

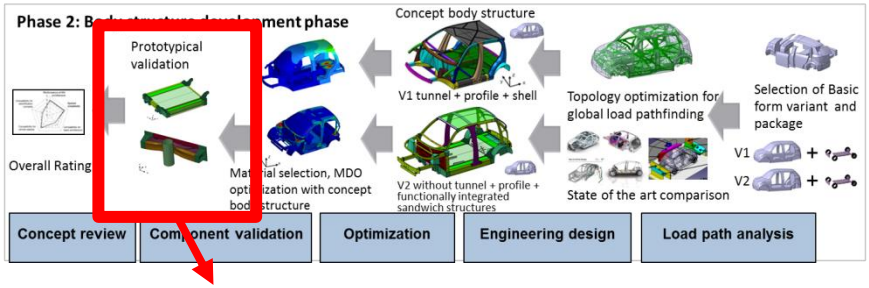
- Crash concept of bottom crash module works
- No intrusion of the battery module

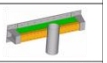


Phase 2: Body structure development phase

Component simulation and experiment

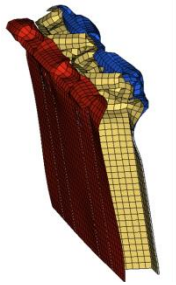


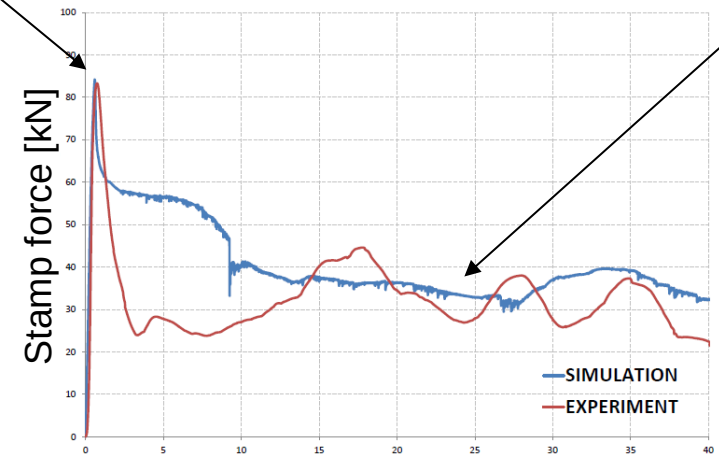


	Complete vehicle	Component	Floor crash concept
Simulation			
Experiment			

Component: Trapezoidal sandwich

Force peak ≈ 83 kN





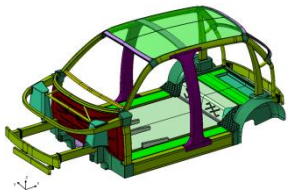
Force level ≈ 36 kN

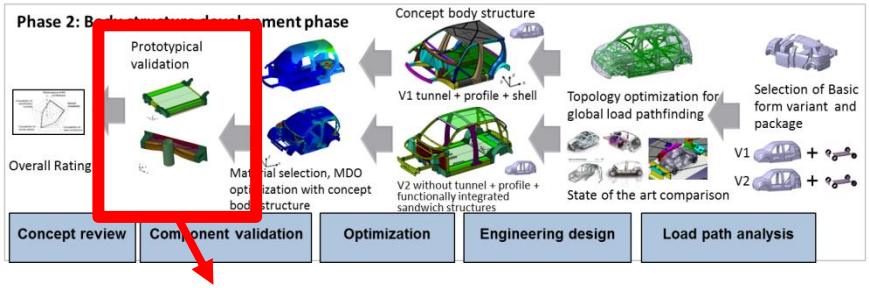
Simulation

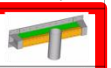
Experiment

Phase 2: Body structure development phase

Floor crash concept simulation





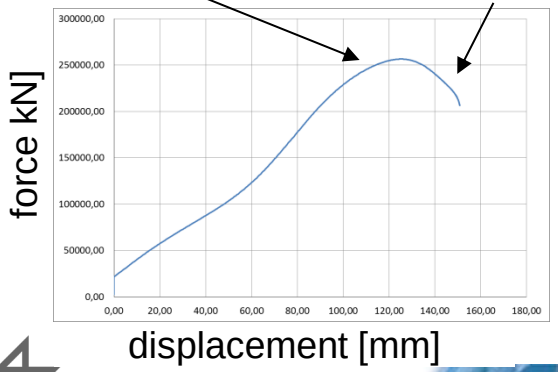
	Complete vehicle	Component	Floor crash concept
Simulation			
Experiment			

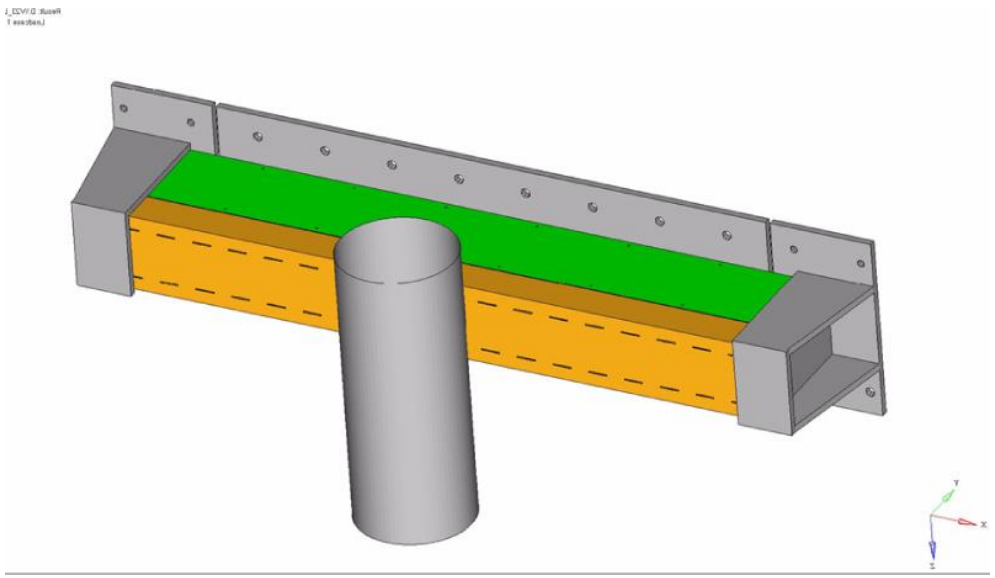
Simulation: Complete crash concept of the floor module

- Impact-mass 750 kg
- Euro NCAP Pole-crash
- v = 29 km/h

Force peak ≈ 242 kN

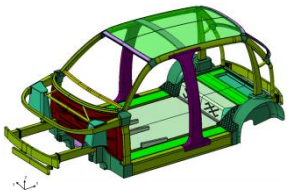
Intrusion ≈ 152 mm

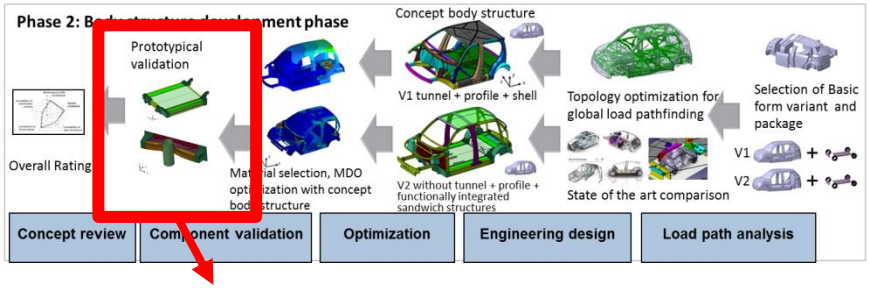


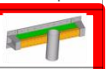


Phase 2: Body structure development phase

Floor crash concept experiment





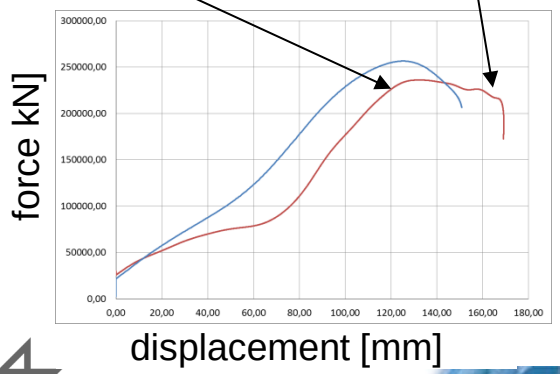
	Complete vehicle	Component	Floor crash concept
Simulation			
Experiment			

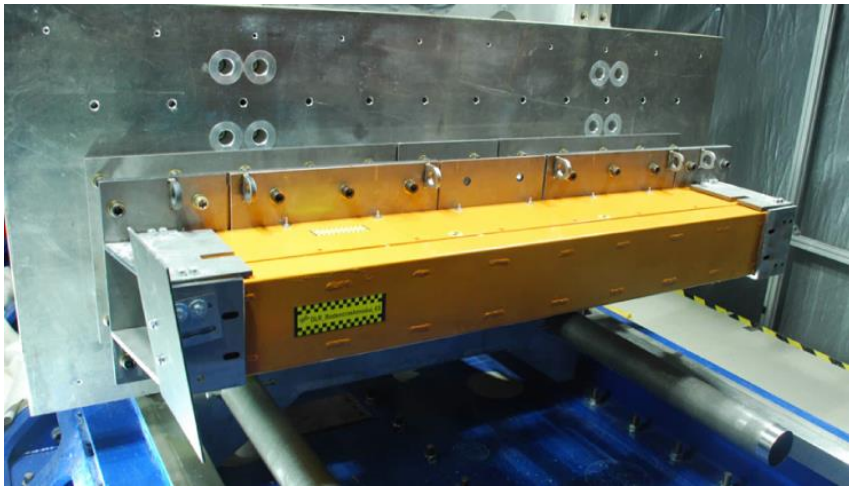
Experiment: Complete crash concept of the floor module

- Impact-mass 750 kg
- Euro NCAP Pole-crash
- v = 29 km/h

Force peak ≈ 237 kN

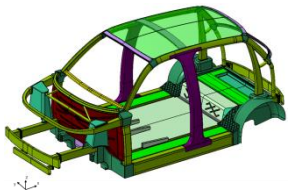
Intrusion ≈ 166 mm

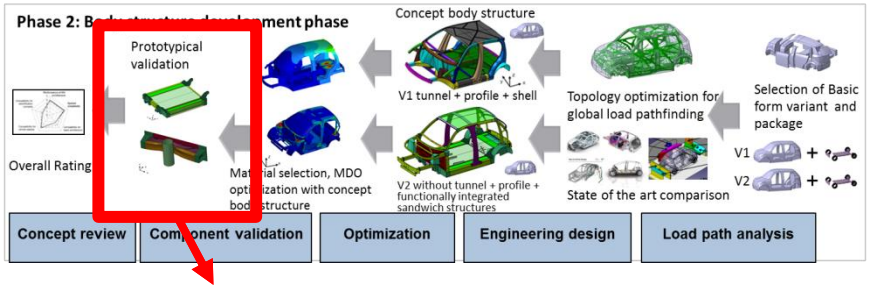


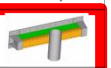


Phase 2: Body structure development phase

Floor crash concept simulation and experiment





	Complete vehicle	Component	Floor crash concept
Simulation			
Experiment			

Comparison: simulation and experiment crashmodul

- Impact-mass 750 kg
- Euro NCAP Pole-crash
- v = 29 km/h

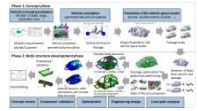
Result:

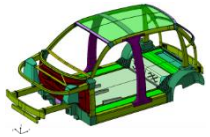
- good correspondence simulation and experiment e.g. intrusion 166 mm

Summery and outlook

Summery:

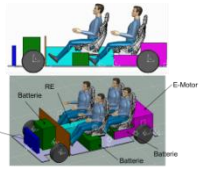
- Holistic development Methodology for vehicle concepts and body structures
- Development of two different vehicle body structures
- Complete vehicle crash simulation
- Prototypical validation of the floor crash concept
- Complete crash of a novel floor module



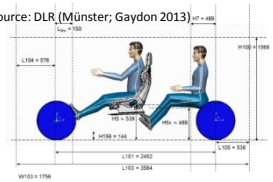


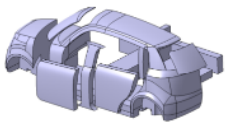
Outlook:

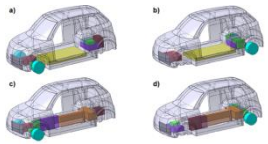
- Detailing the entire body structure and virtuel simulation/optimization
- Prototypical validation other body in white components
- Prototypical construction of complete vehicle structure



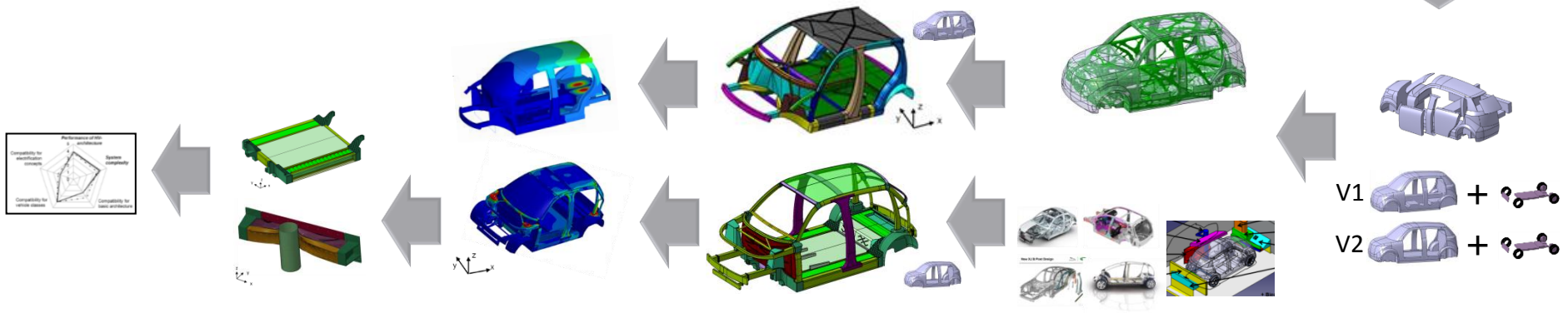
Source: DLR (Münster; Gaydon 2013)


Source: DLR (Münster; Gaydon 2013)


Source: DLR (Münster; Gaydon 2013)



Thank you for your attention



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