Development of the Safe Light Regional Vehicle (SLRV) vehicle concept within the DLR Next Generation Car (NGC) project

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Locations and research areas

The German Aerospace Center (DLR) is the national aeronautics and space research center of the Federal Republic of Germany.

DLR has approximately 8000 employees at 20 locations in Germany and international offices in Brussels, Paris, Tokyo and Washington D.C.

- Aeronautics
- Space Research and Technology
- **Energy and Transport**
- Defence and Security
- Space Administration
- Project Management Agency

Research at the Institute of Vehicle Concepts

Mega trends

- Globalization
- Megacities
- Industry 4.0
- Digitalization
- Connectivity
- Big Data

Traffic turn / Energy Turn

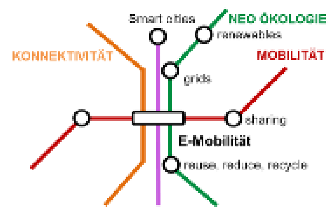
Automated / Autonomous Drive

- Climate change
- Energy efficiency
- Resources efficiency
- Energy source
- CO_2

Require-ments

- Sustainability
- Safety
- Comfort
- Affordability

- Modularity
- Individuality
- Flexibility
- Economy of time



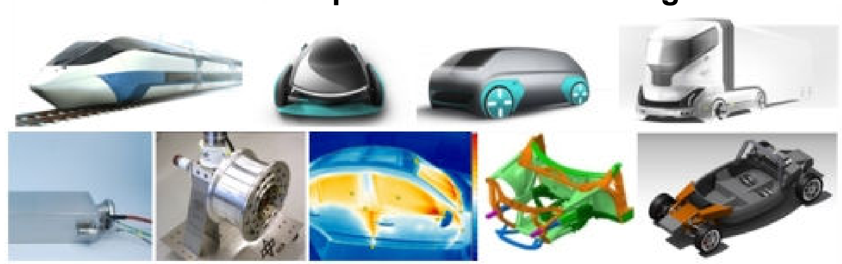
- Energy efficiency
- Resources efficiency
- Free of emissions
- Cost efficiency

- Intermodality
- Connectivity
- "Shared"
- "Smart"

Solution

- Powertrain
- Energy conversion
- Energy storage
- Fuel cells
- Range Extender

Vehicle concepts / Vehicle technologies

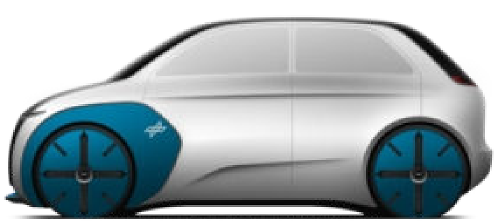


Energy source and fuels

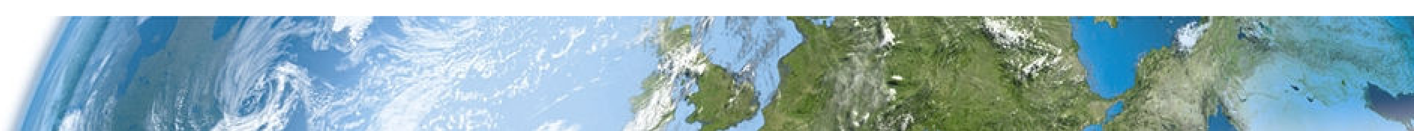
- Lightweight
- Materials
- Design
- Production

DLR Next Generation Car (NGC) Concepts

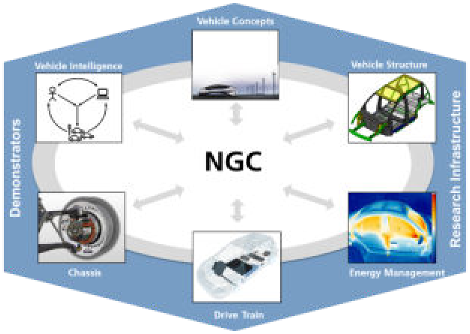
Urban Modular Vehicle (UMV)	Safe Light Regional Vehicle (SLRV)	Interurban Vehicle (IUV)



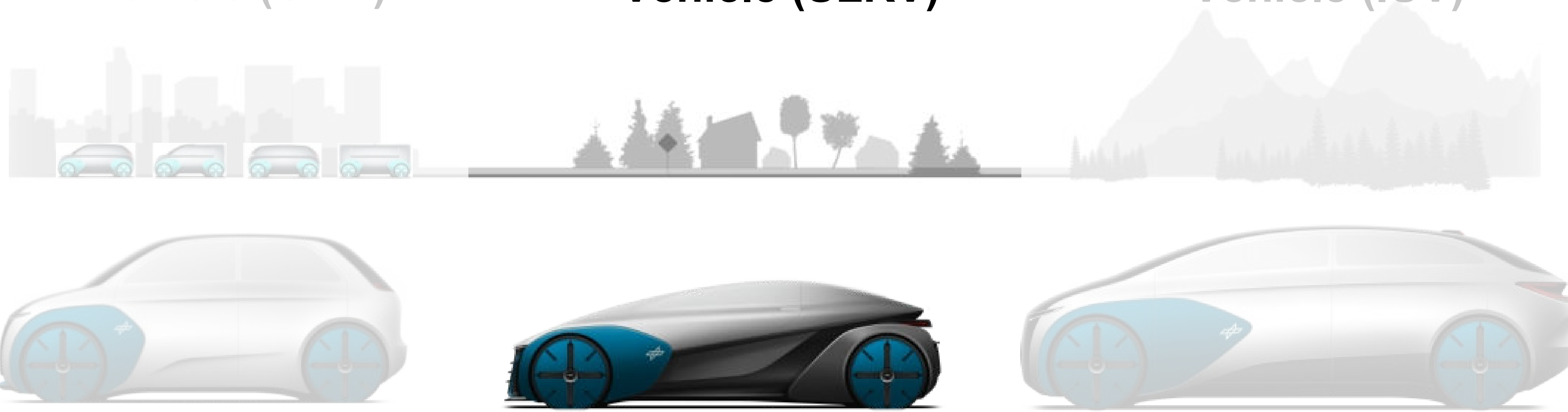
Urban, smart electric vehicle with modular design	Economical, lightweight and safe L7e class vehicle	Comfortable fuel cell vehicle with fibre composite body



DLR Next Generation Car (NGC) Concepts



Urban Modular Vehicle (UMV)	Safe Light Regional Vehicle (SLRV)	Interurban Vehicle (IUV)



Urban, smart electric vehicle with modular design	Economical, lightweight and safe L7e class vehicle	Comfortable fuel cell vehicle with fibre composite body

DLR

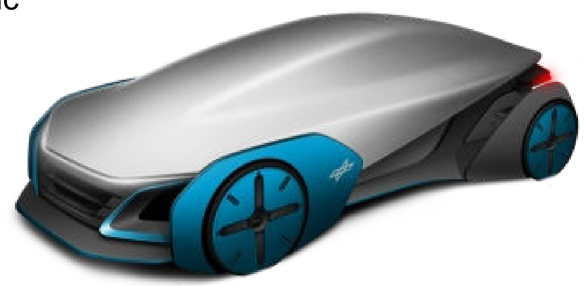
NGC – Safe Light Regional Vehicle (SLRV) Overview

Vehicle intelligence
- Partially automated driving
- Full automation in emergency situations with cooperative swerving
- Connected driverless parking with integration in infrastructure and traffic or parking space management

Vehicle concept
- Light, safe L7E class vehicle
- **Kerb weight max. 400 kg**
- **Range: 400 km**
- The most streamlined design possible
- Quantity (target): 50,000/year

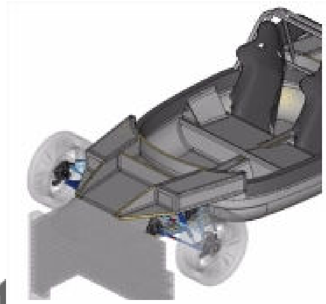
Vehicle structure
- Metal-foam sandwich structure
- Body in white weight < 90 kg
- Crash safety according to state of the art technology for passenger cars (M1 class)

Source: DLR



Source: DLR

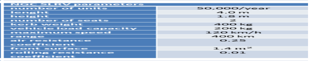
Chassis
- Crash-optimal designed double wishbone suspension axle
- Drive-by-wire steering



Drive train/energy storage
- 2 x 7.5 kW motors near the wheel
- Fuel cell - battery hybrid with structure-integrated energy storage
- Cooling concepts for the hybrid battery

Energy management
- Use of waste heat from the fuel cell system
- Targeted use of the insulating effect of sandwich structures
- Use of process cooling from hydrogen storage

Energy and Performance Requirement:

NGC SLRV parameters	
number of units	50,000/year
lenght	4.0 m
height	1.8 m
number of seats	2
kerb weight	400 kg
vehicle load capacity	200 kg
maximum speed	120 km/h
range	400 km
air resistance coefficient	0.25
front surface	
rolling resistance coefficient	0.01

Vehicle concept	SLRV	
Driving profile	NEFZ	WLTP C2
Specific energy consumption [kWh/100km]	**5,6**	**4,5**

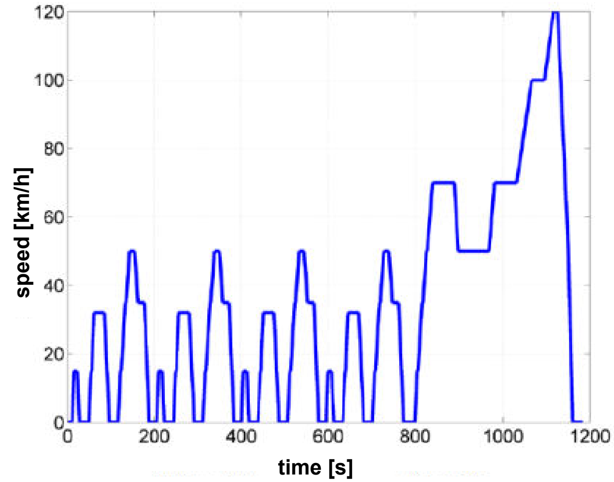
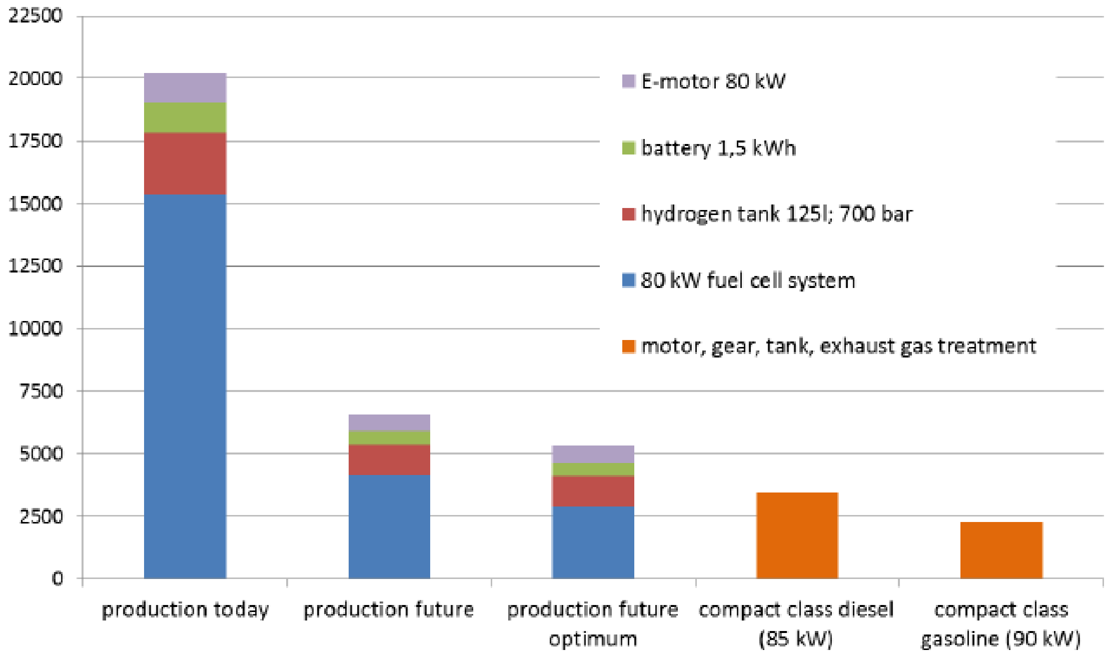


Figure 1: driving speed profile of the NEFZ

- SLRV fuel consumption: **0.34 kg** H2/100 km
- Comparison with Toyota Mirai: **0.76 kg** H2/100 km

- Comparatively low energy requirement, due to low driving resistance
- Required power of the fuel cell in the SLRV: 8 kW + 25 kW hybrid battery

Predicted cost of a 80 kW Fuel Cell System



SLRV data

- Electric motors: 2 x 7.5 kW
- Battery: 1,5 kWh
- Fuel cell: 8.5 kW

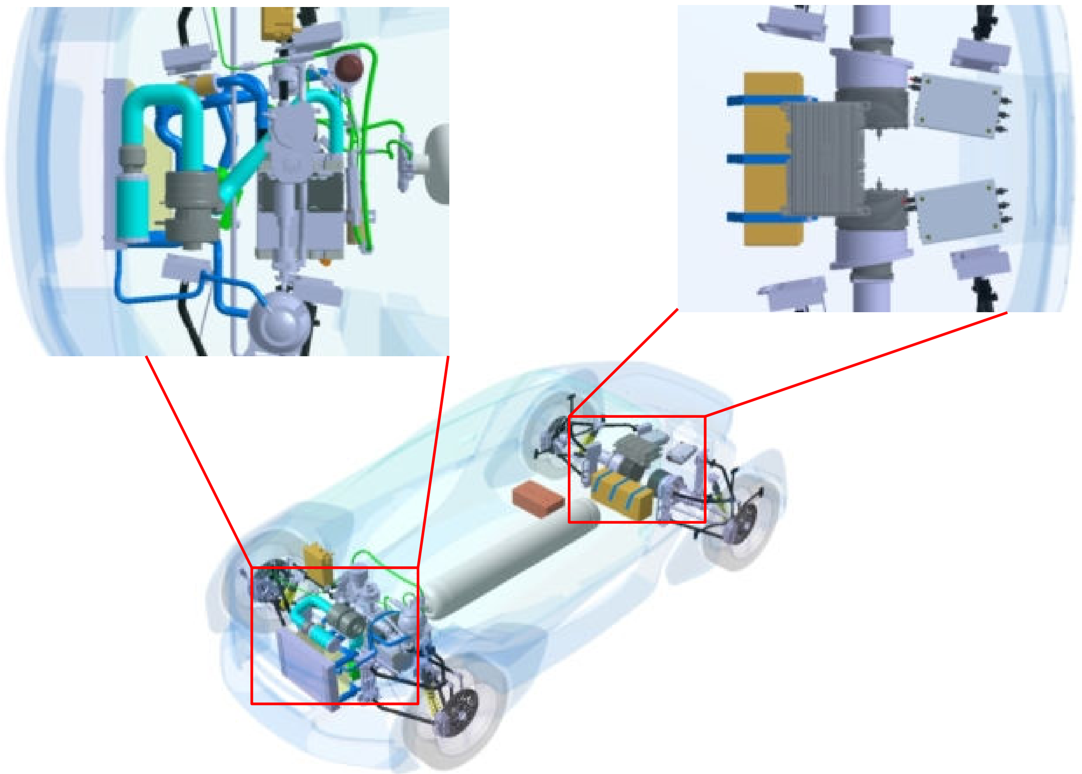
Source: S. Ehrenberger, Evaluation of Fuel Cell Drivetrains, LCM 2015

- Power output of the SLRV fuel cell system: 8.5 kW -> scaling factor?
- Cost estimate for the vehicle body (mass production) approx. € 600 production costs

Drive train concept

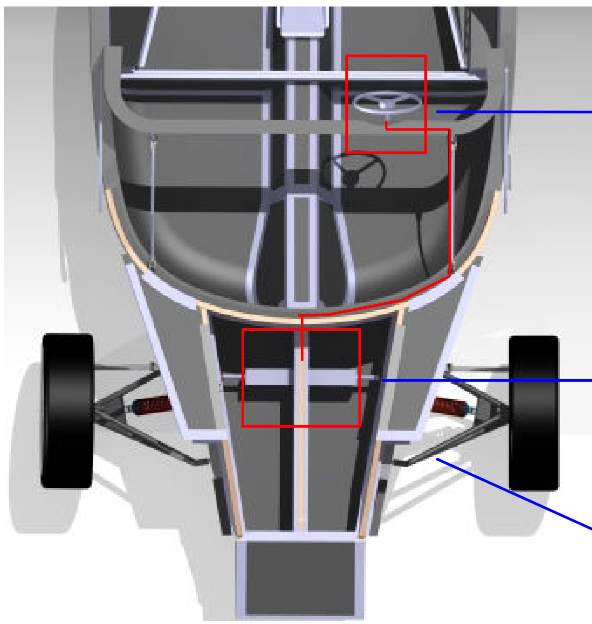
Fuel cell system

Battery and electric motors

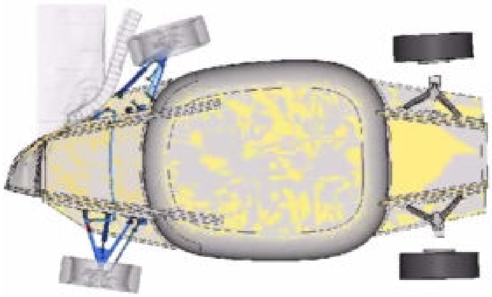


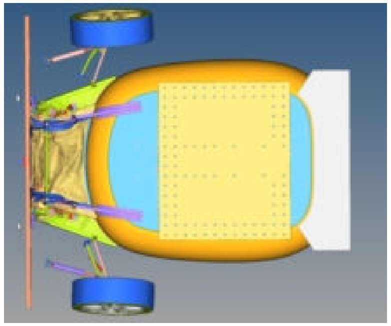
- Fuel cell stack in the front of the vehicle -> minimal pipe length for coolant and H_2
- H_2 pressure tank 700 bar, placement in the tunnel
- Two permanent magnet synchronous motors, no differential gear

Concept of the Front Chassis and Steering



- Steering and accelerator pedal: drive-by-wire
- Brake: hydraulic + energy recovery using the electric motors
- Actuator
- Triangle wishbone suspension chassis





- Drive-by-wire steering: no need for a steering column and associated structures -> added flexibility for the interior layout
- Double wishbone suspension: impact of the wheels with the passenger compartment should be avoided

SLRV Vehicle Structure

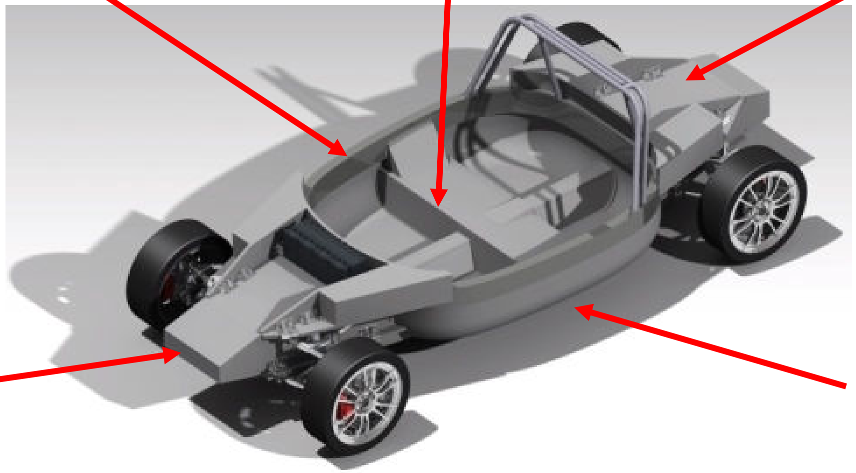
SLRV vehicle body in metal sandwich construction: weight 90 kg

Surrounding ring structure with sandwich core

- Energy absorption in side and pole crash
- Force path in the frontal crash cases

Integrated seating bench

Rear vehicle section with sandwich construction



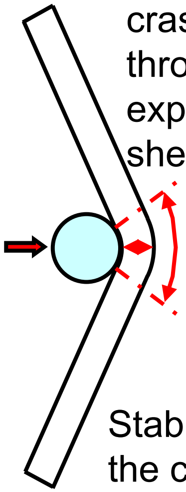
Front vehicle section in sandwich construction

- Energy absorption in the frontal crash load cases
- Absorption of chassis structural loads

Floor tray as 3D sandwich component

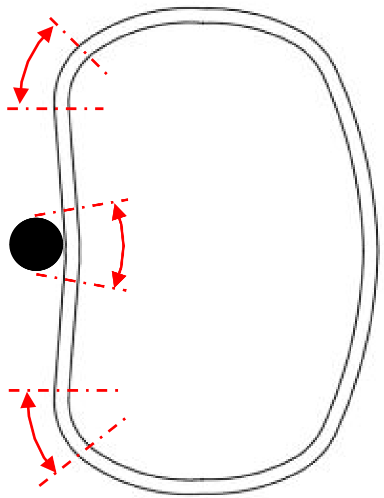
Example: sandwich element

Function of the Ring Structure in the Event of a Crash



Absorption of crash energy through the expansion of the shell

Stabilisation of the cross section

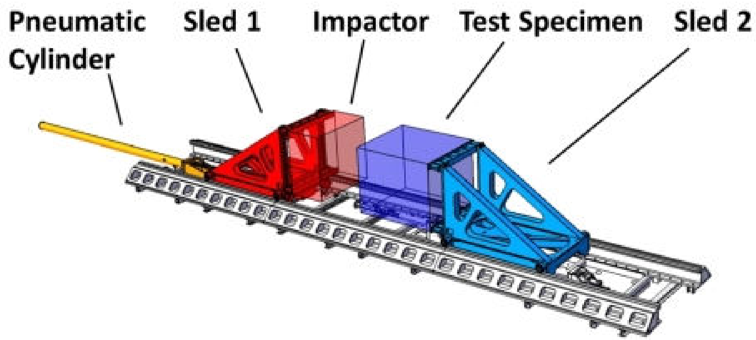


Ring-shaped structure with core for distribution of expansion over an even larger area

Ring structure with test setup

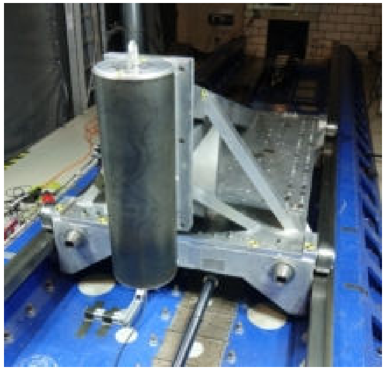
- Production of the ring-shaped structure made of stainless steel sheet metal
- Filling with BETAFOAM™ PUR foam from Dow Automotive Systems

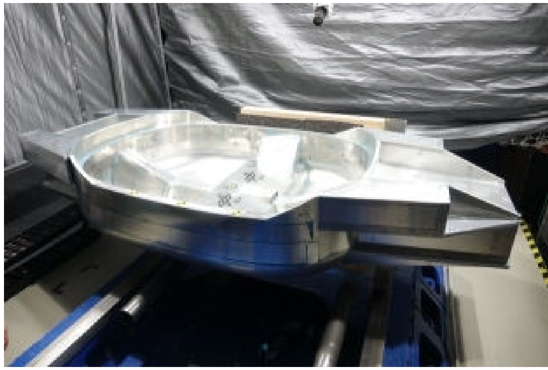
Setup of the crash tests



Pole crash test

	Mass [kg]	Velocity [m/s]	Velocity [km/h]	Energy [kJ]
SLRV complete vehicle crash simulation	530	8,06	29,00	17,20
Impactor sled	748,40	6,78	24,41	17,20
Values in test	748,40	6,8	24,48	17,30



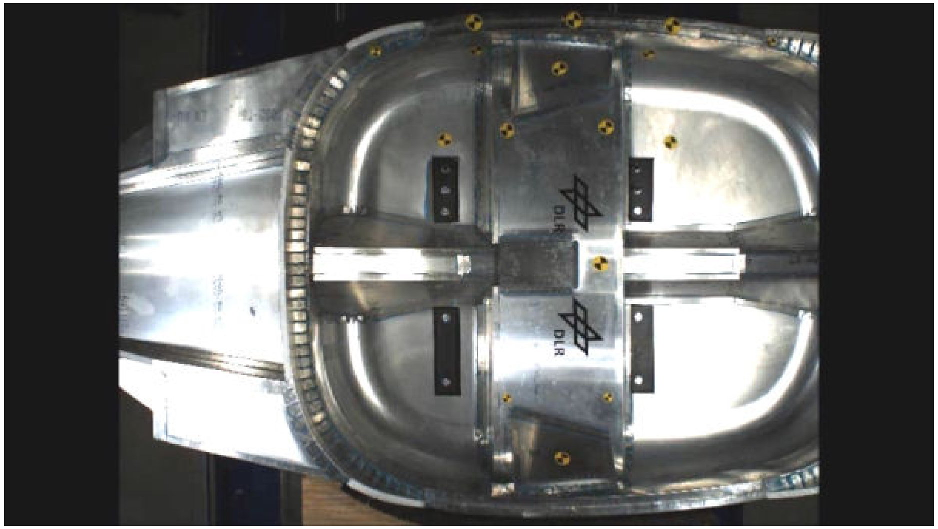


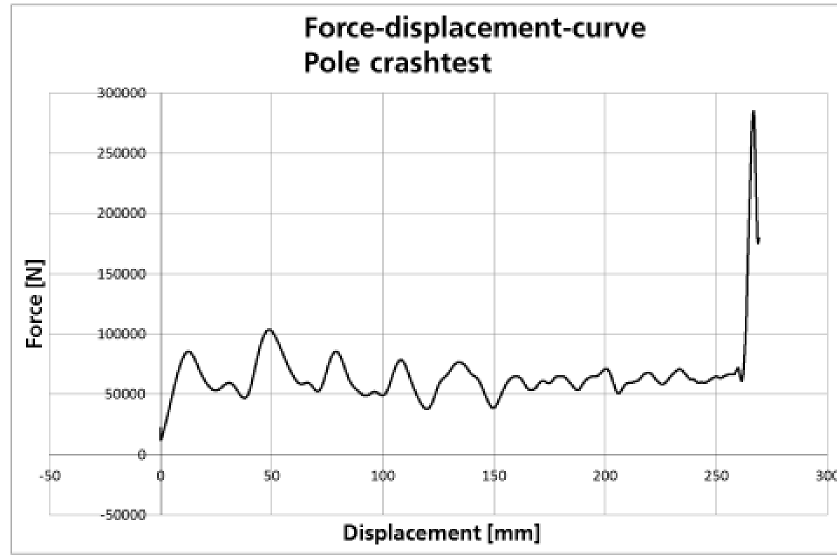
Frontal crash

	Mass [kg]	Velocity [m/s]	Velocity [km/h]	Energy [kJ]
SLRV complete vehicle crash simulation	530	15,56	56,00	64,12
Impactor sled	826,40	12,46	44,85	64,12
Values in test	826,40	13,30	47,88	73,09

Sled weight is higher than the vehicle weight -> reduction of test speed to achieve the same impact energy

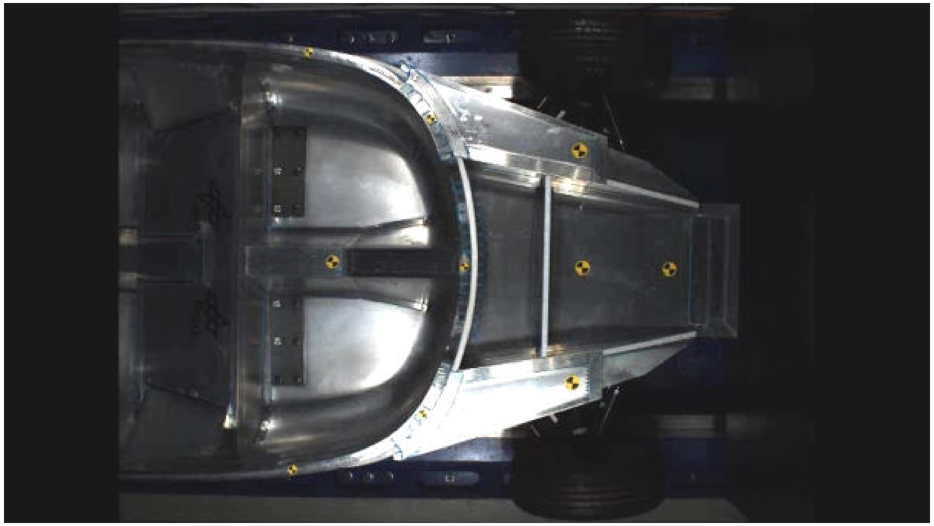
Crash test results, pole crash

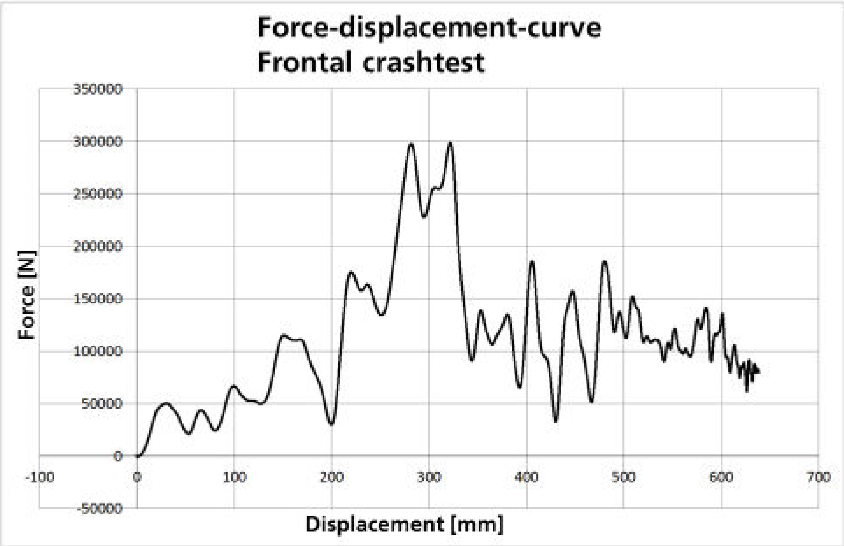




- Uniform deformation behavior, without any major reduction in force
- Support structure between seat and ring did not perform well in this test
- Local debonding of adhesive joints which was not predicted in the simulation
- 90 % of the impact energy was absorbed by the vehicle structure, maximum Intrusion of 280 mm

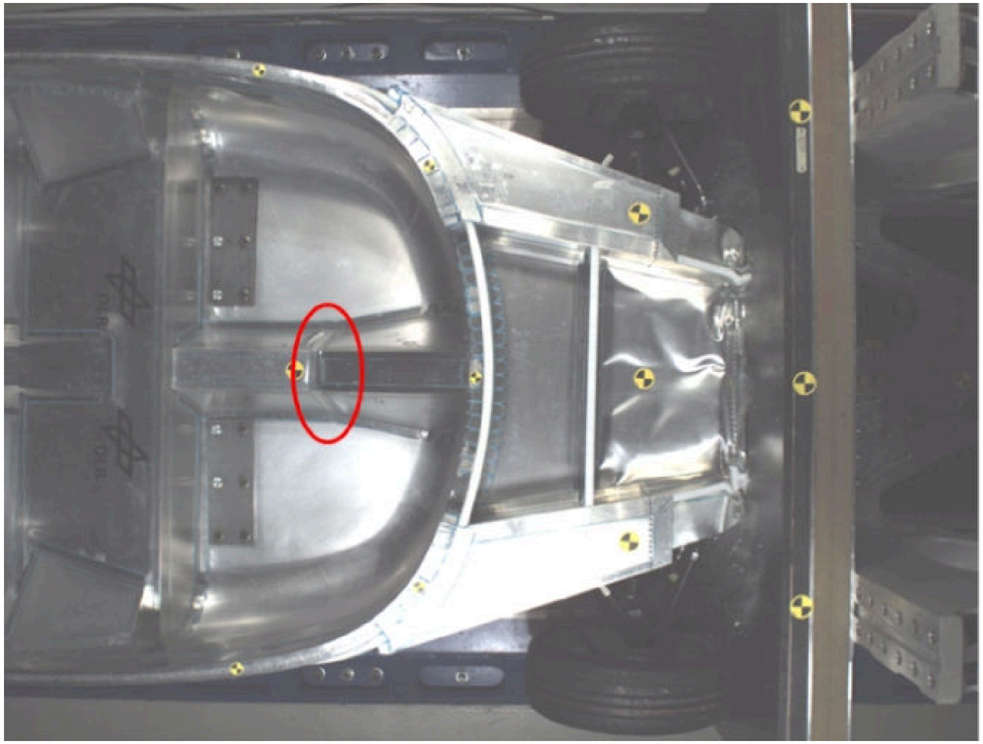
Crash test results, full frontal crash





- Continuous deformation of the front structure, without any major reduction in force
- Peak of around 250 kN as the Barrier impacts the wheels
- Impact of the wheels on the passenger compartment was avoided successfully
- Use of ropes with integrated energy absorbers to restrain and slow down the wheels
- No intrusion into the passenger compartment
- Good correlation of simulation and test results

Behaviour of the passenger compartment during the frontal crash test

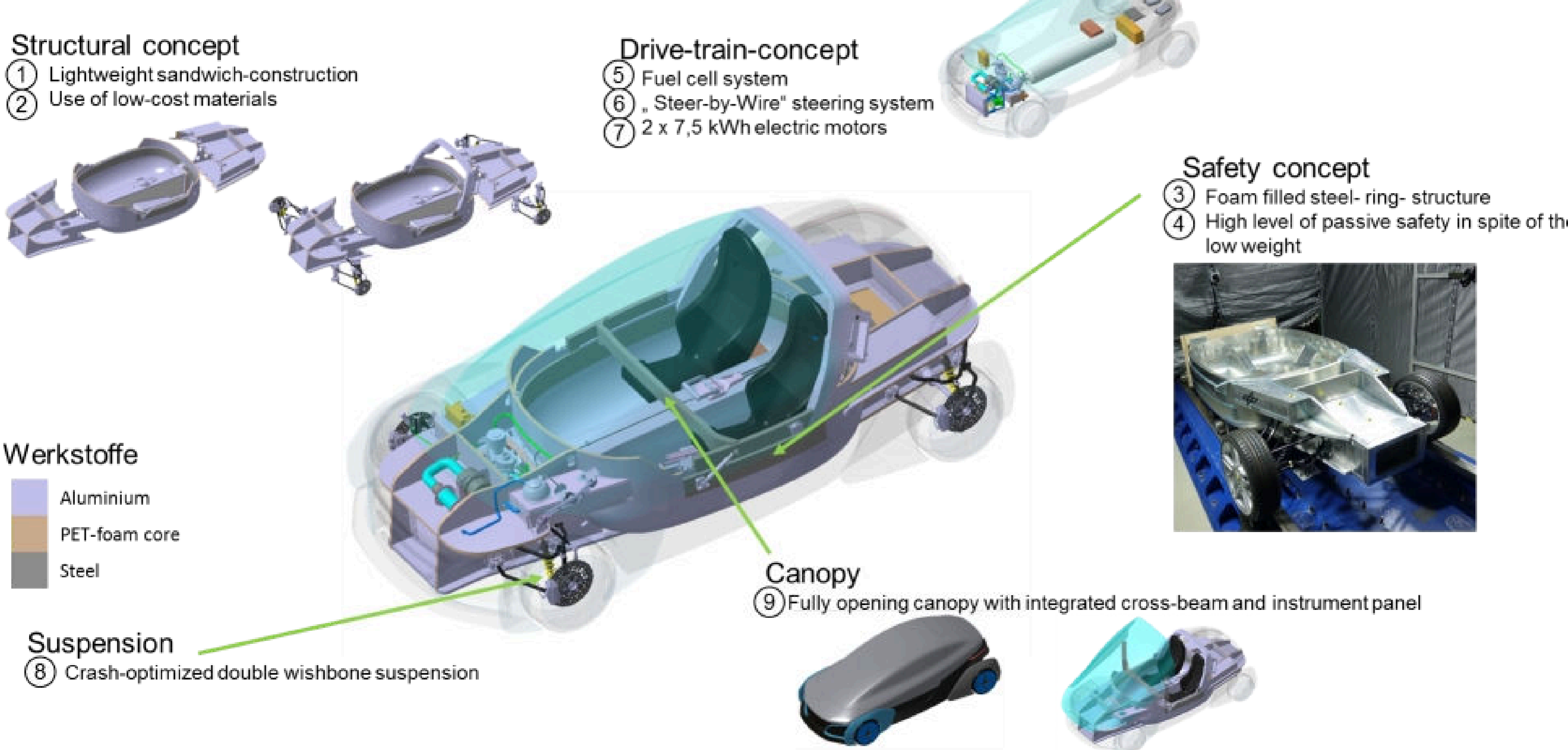


- Slight deformation of the tunnel, otherwise only elastic deformation
- No intrusion into the passenger compartment

Summary

- Lightweight vehicle concept based on a metal intensive sandwich structure and a fuel cell drive train
- Low driving resistance leads to reduced energy and power requirements of the vehicle
- More work necessary in the modelling of the adhesive for simulation; the adhesive itself however has excellent crash performance
- Good overall crash performance of the Sandwich structure, especially in the frontal crashtest
- Validation of key concepts, e.g. the deformation of the ring structure and the crash behaviour of the double-wishbone suspension

Outlook



- Construction of technology-demonstrators of all 3 NGC vehicle concepts
- Construction of a driveable demonstrator of the SLRV

Thank you for your attention!

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