# Innovation Examples for Ecological Vehicles based on Aerospace Research

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Institute of Vehicle Concepts
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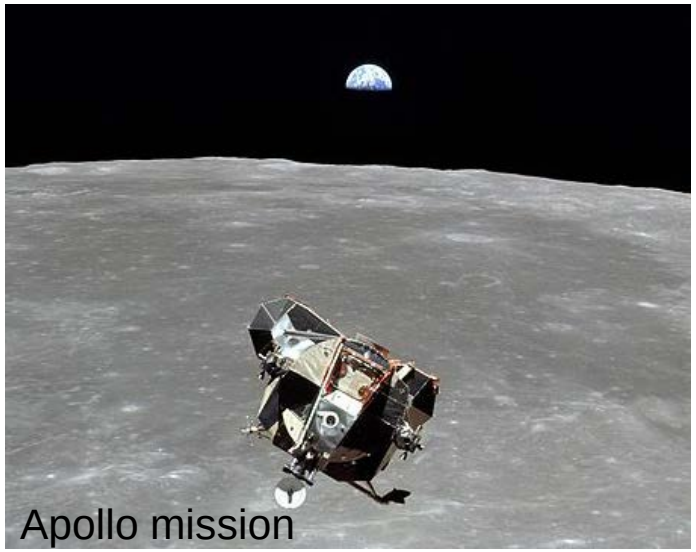
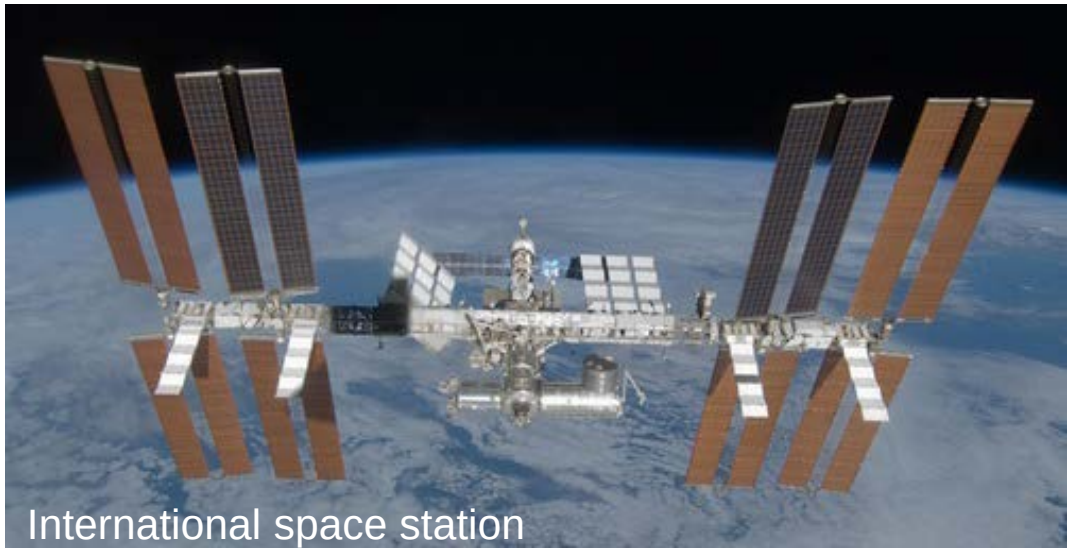
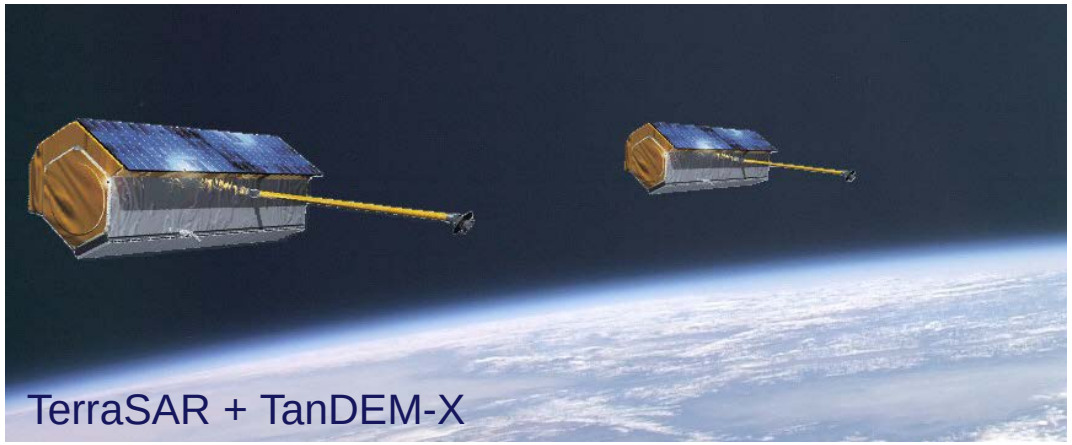
# Remember 50 years of space research in our planetary system



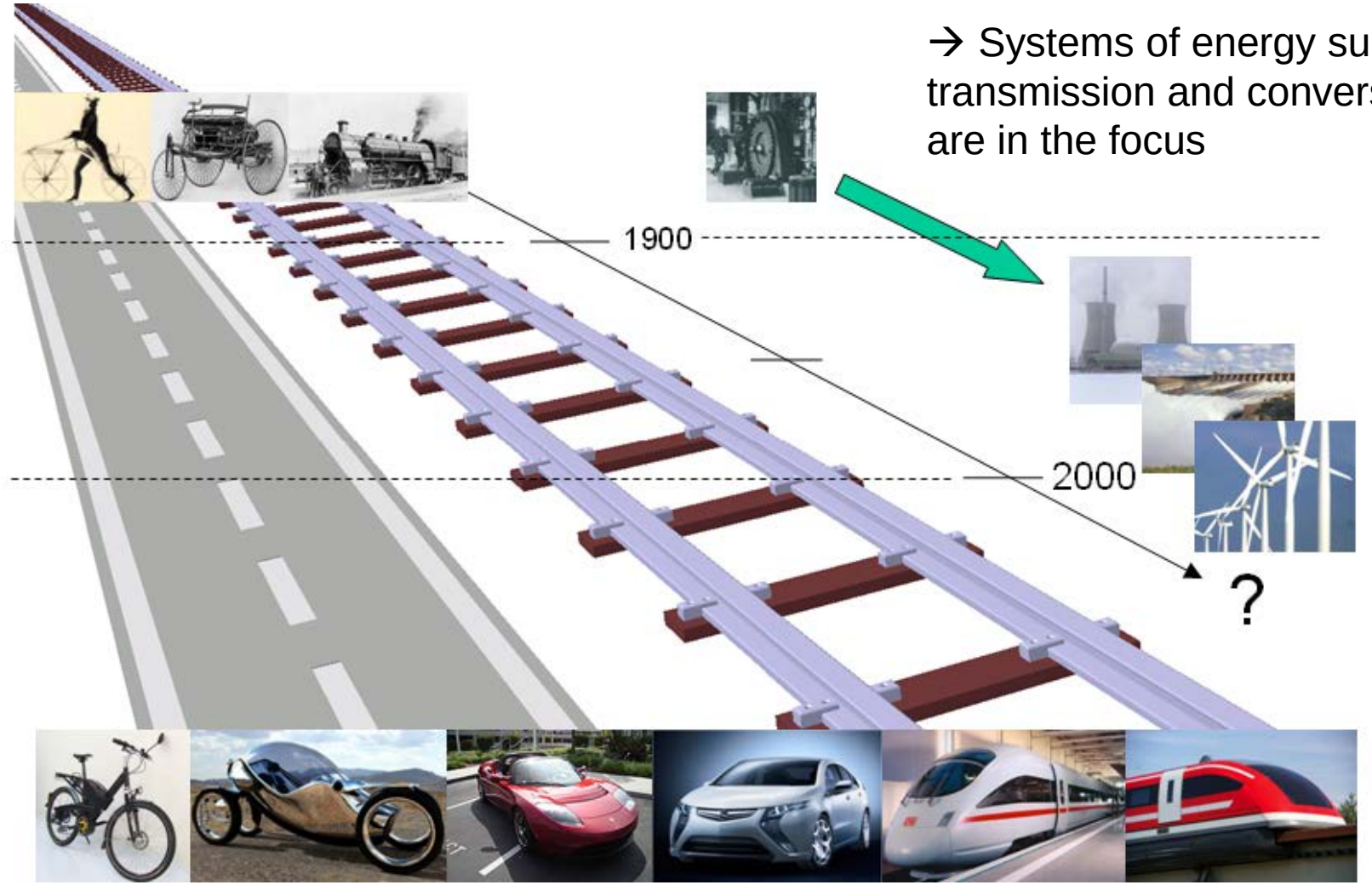








→ electric mobility on earth - how to design the trip to the future?

# Electric mobility on earth – how to design the trip to the future?



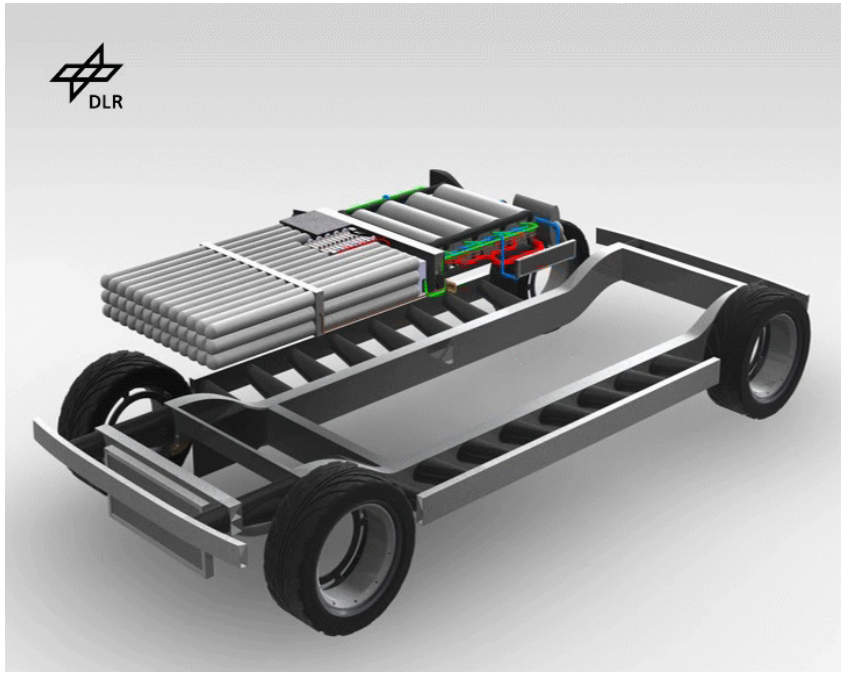

→ Systems of energy supply, transmission and conversion are in the focus



# Content

- Using synergies from the aerospace research

- Carbon fibre reinforced plastic rib construction
- Thermal management
- Fuel cell systems
- Free piston linear generator
- Micro gas turbine
- Thermoelectric energy conversion
- Wheel hub motors




# Using the Synergiy Potential from the Research Infrastructure

- from space, aviation, energy, traffic




- fron research test benches:

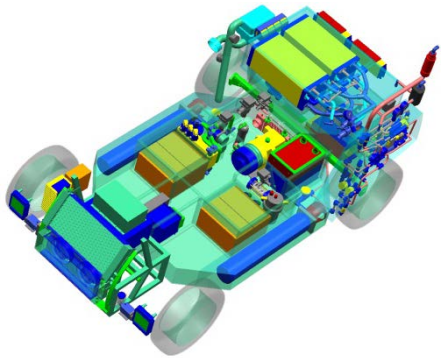




- fron test vehicles:

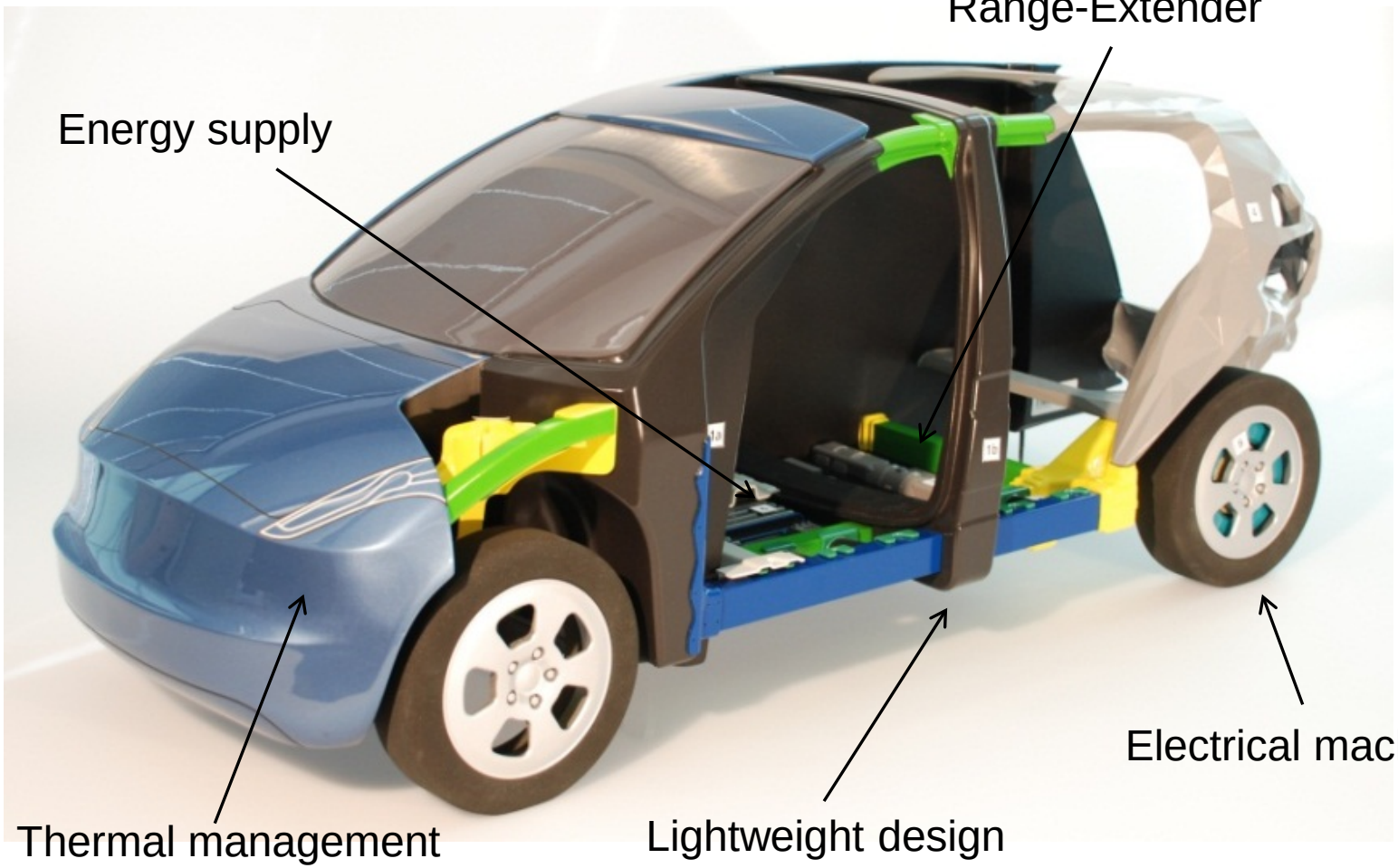


# Optimization of Vehicle Energy Concepts

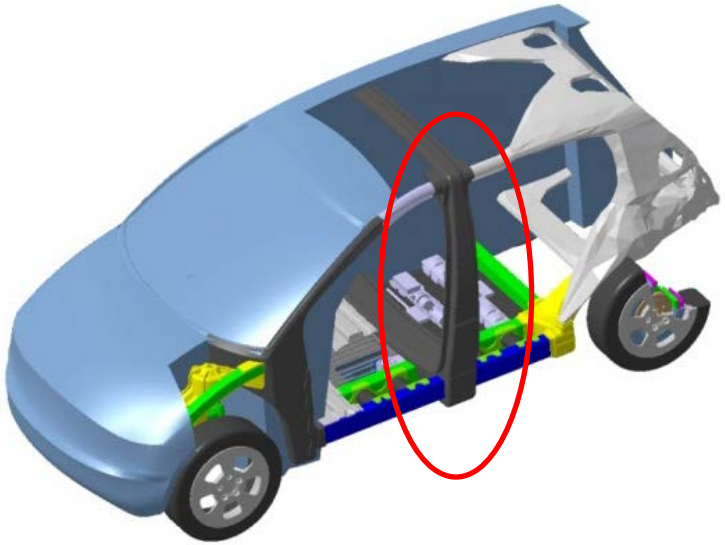


- Total system projection for road and rail vehicles of the future
- Increasing of efficiency by optimizing of operation strategies of hybrid- and electric vehicles
- Innovative drive concepts
- Utilisation of unused energy (waste heat)
- Improvement of special energy conversion processes
- Integration of new fuels and energy carriers like hydrogen or electric energy
- Systemic merging of technologies
- High integration of functions
- Decreasing of the driving resistances

# Examples to optimize Vehicle Energy Concepts




→ **Reducing the driving resistances and increasing the efficiency**

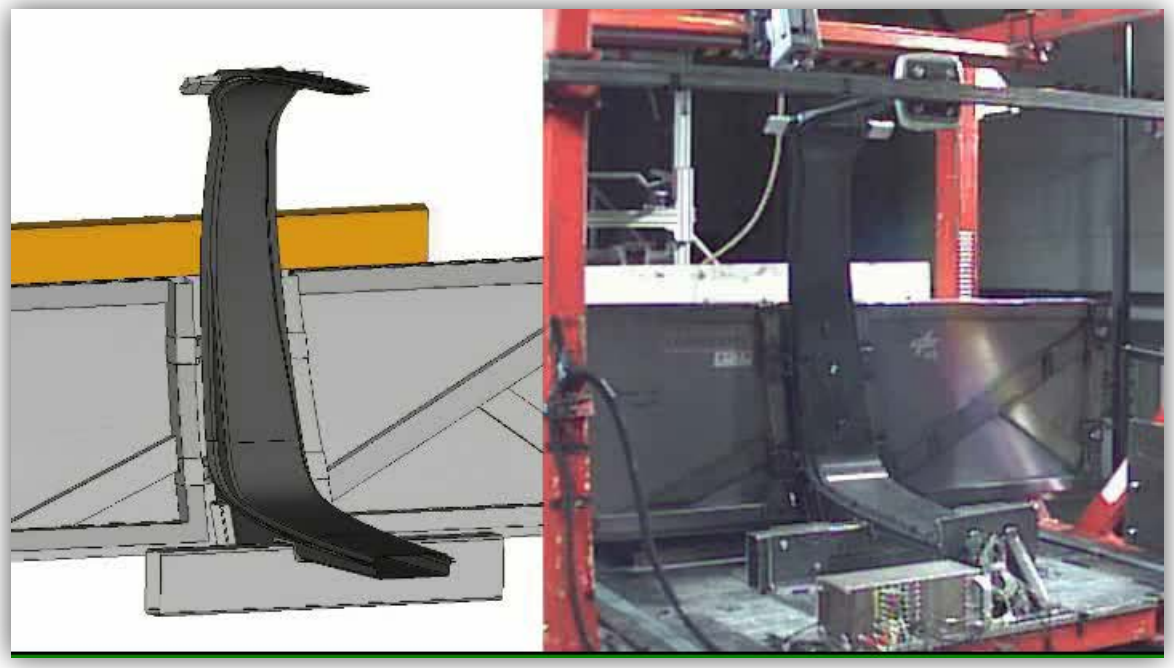


# Carbon Fibre reinforced Plastic Rib Construction

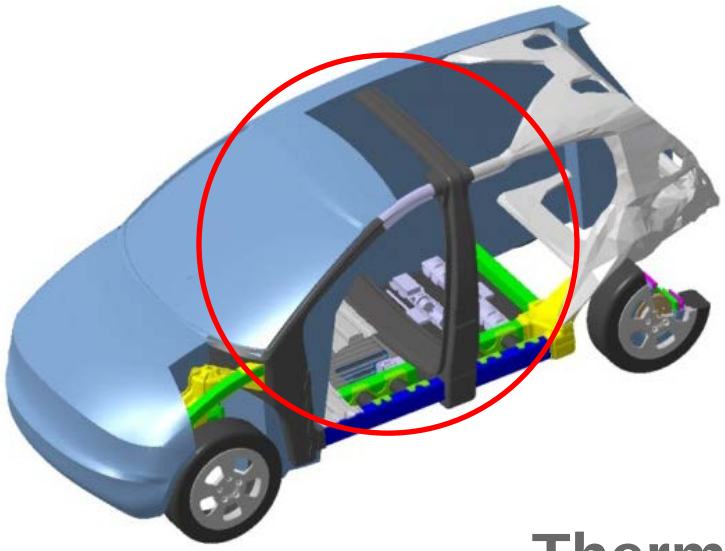
# Carbon Fibre reinforced Plastic Rib Construction

Quelle: DLBS


# Carbon Fibre reinforced Plastic Rib Construction

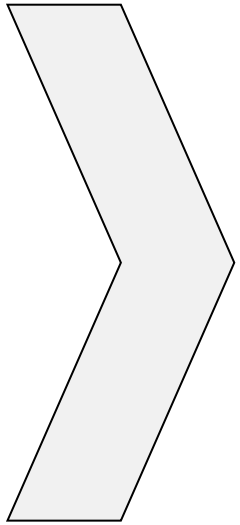


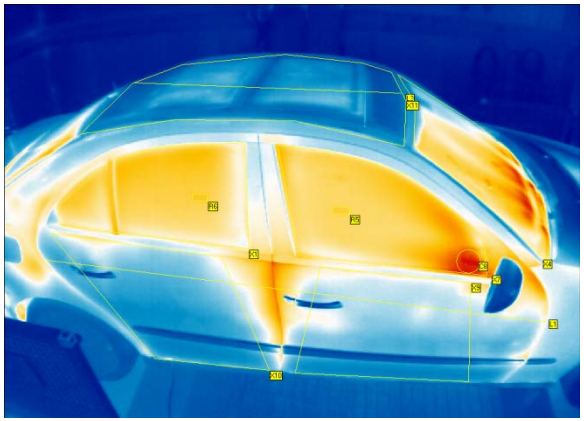
Lightweight rib construction showing the side crash behavior to guaranty the safety of the passengers



# Thermal Management

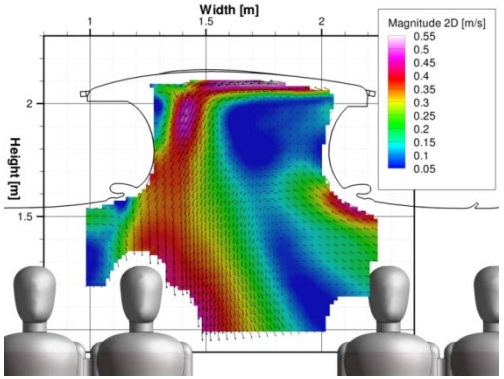
# Cabin Thermal Management





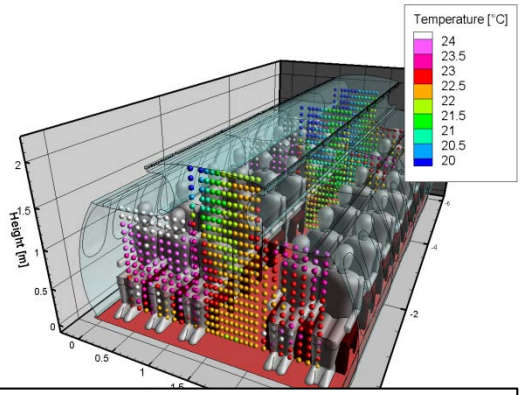
# Cabin Simulation and Verification Synergies from the Aviation Sector

Passenger dummies

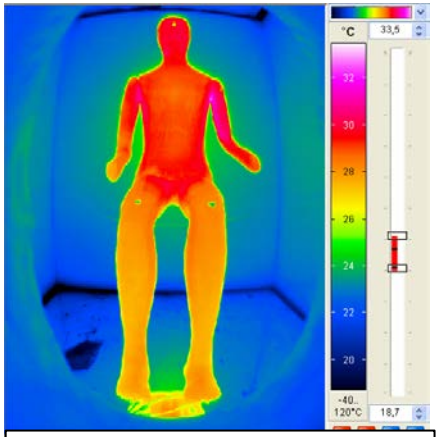



Particle Image Velocimetry

multi-colour laser-visualisation




Simulation of cabin-aerodynamics with full-scale-models

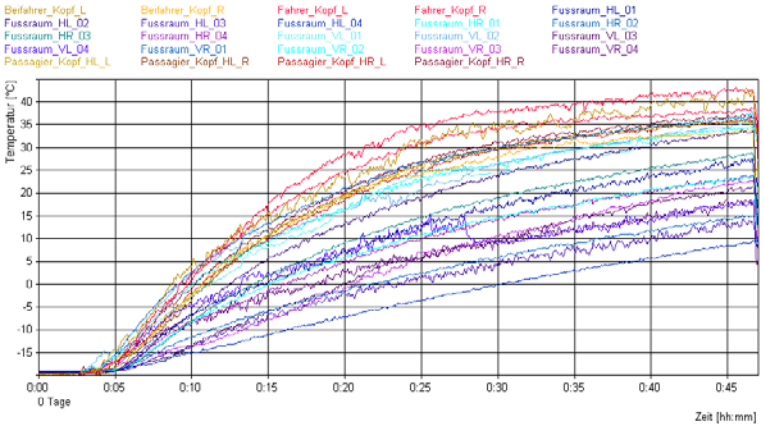


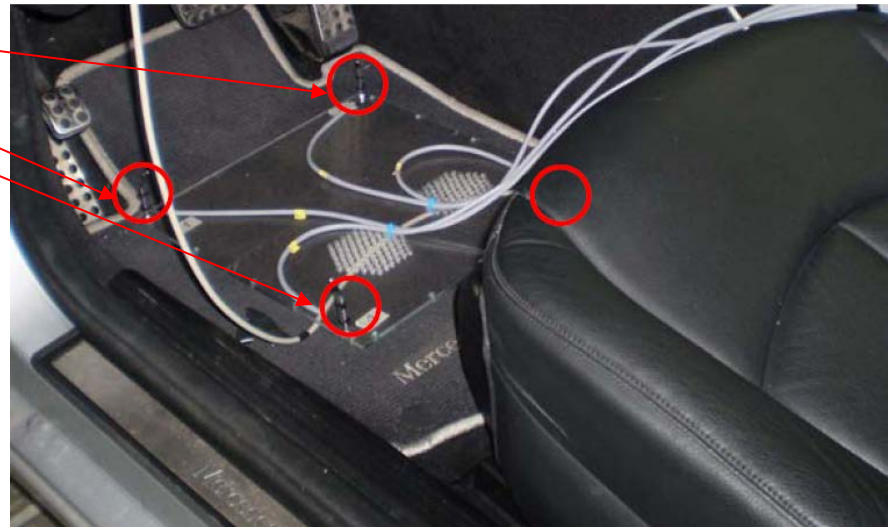

Thermal passenger models

# Cabin Simulation and Verification

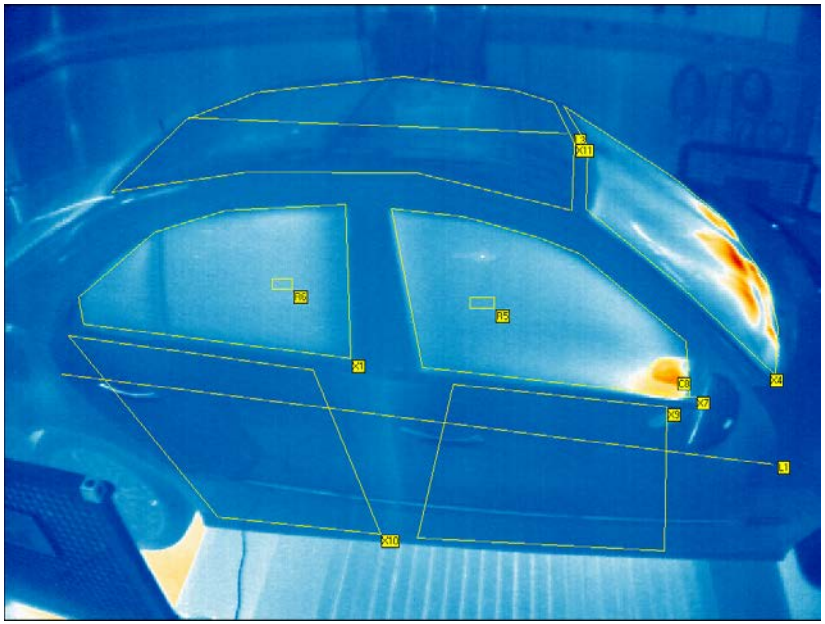
measuring the temperature while heating up the cabin

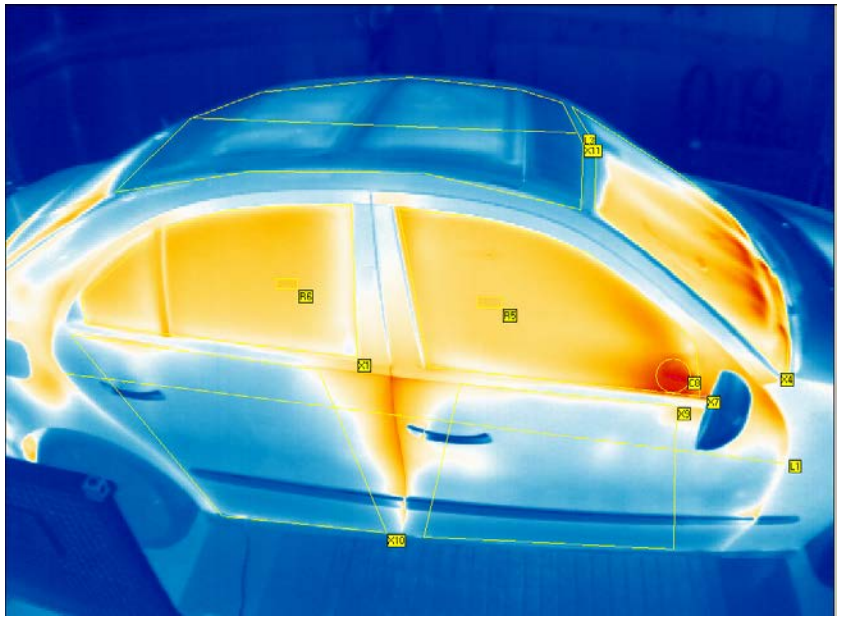
temperatur-sensors



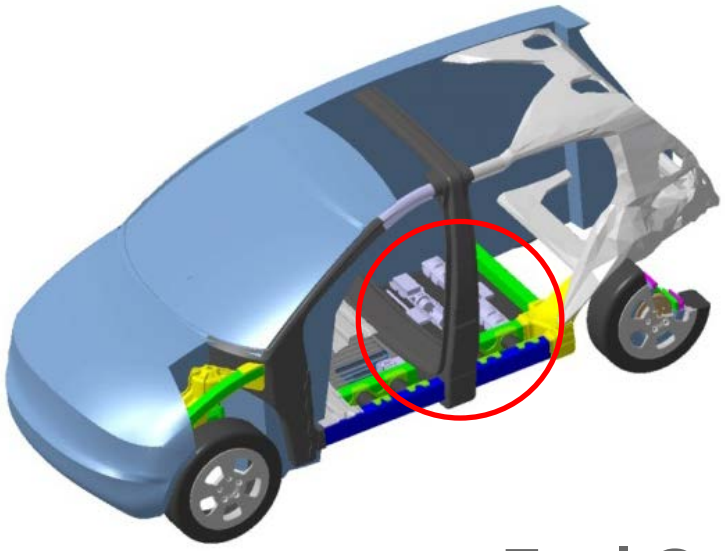



# Cabin Simulation and Verification



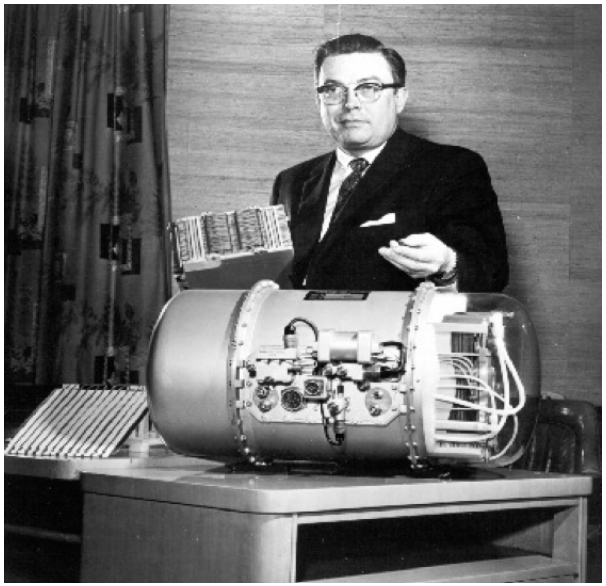


verification of cabin simulation (gaps, isolation parts, thermal resistances) on the roller test bench



# Fuel Cell Technology

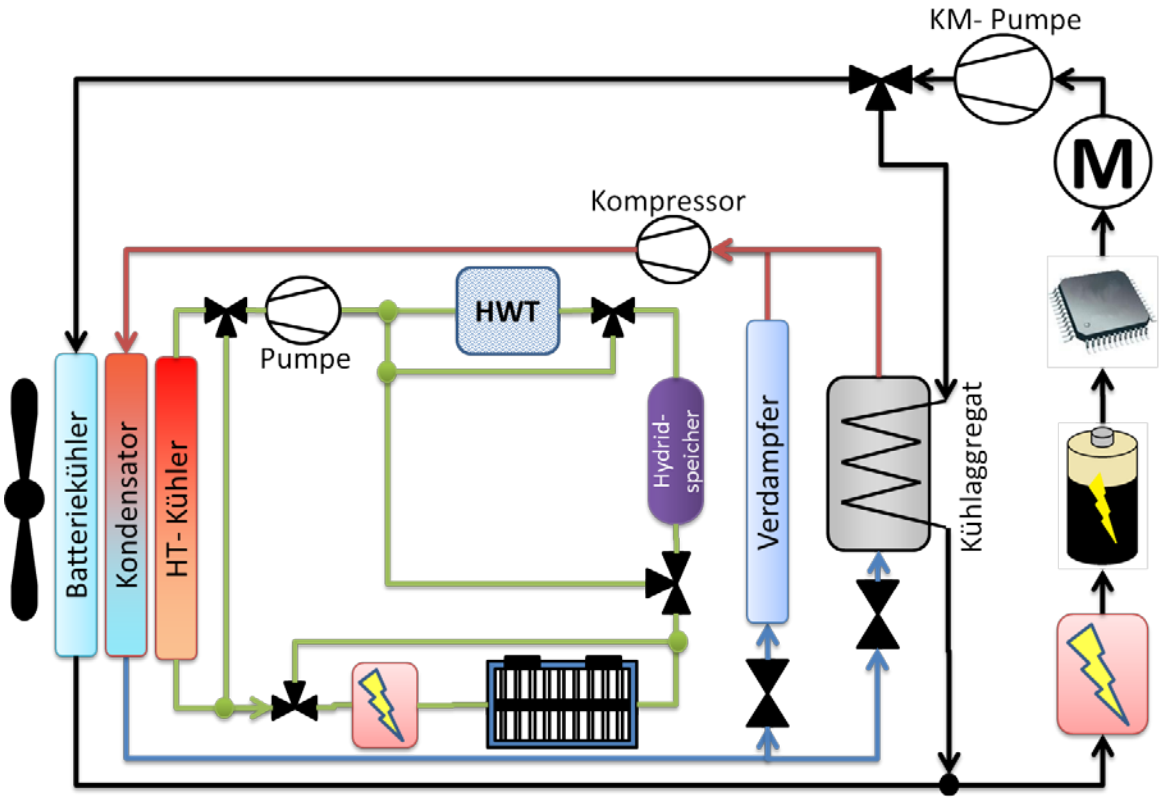
# Fuel Cell Systems



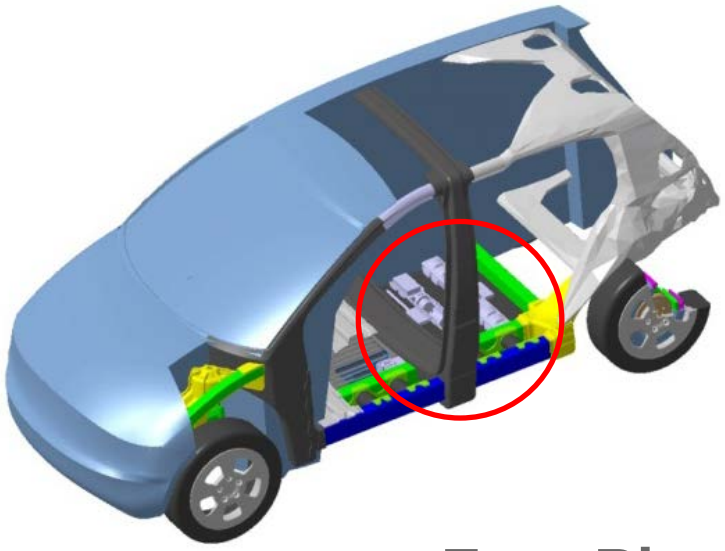
Quelle: FH Darmstadt

Increasing of efficiency by optimizing of operation strategies of hybrid- and electric vehicles

# Fuel Cell Thermal Management




- Thermal management of the HVAC-circuit,
- the coupling of high temperature PEM-fuel cell and hydrogen storage and
- the components battery, inverter and motor



# Free Piston Linear Generator

Improvement of special energy conversion processes

Systemic merging of technologies

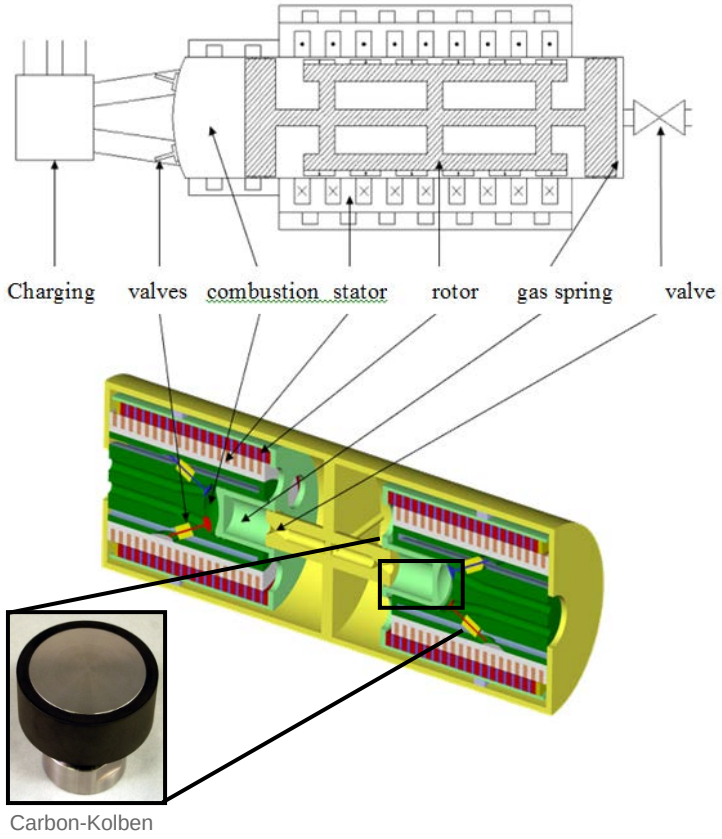
# Electric Energy Supply with the Free Piston Linear Generator

**Advantages:**

- Variable compression
- Variable piston distance
- No crank shaft, no cam shaft
- No throttling
- No side forces to the piston
- Packaging
- Online downsizing

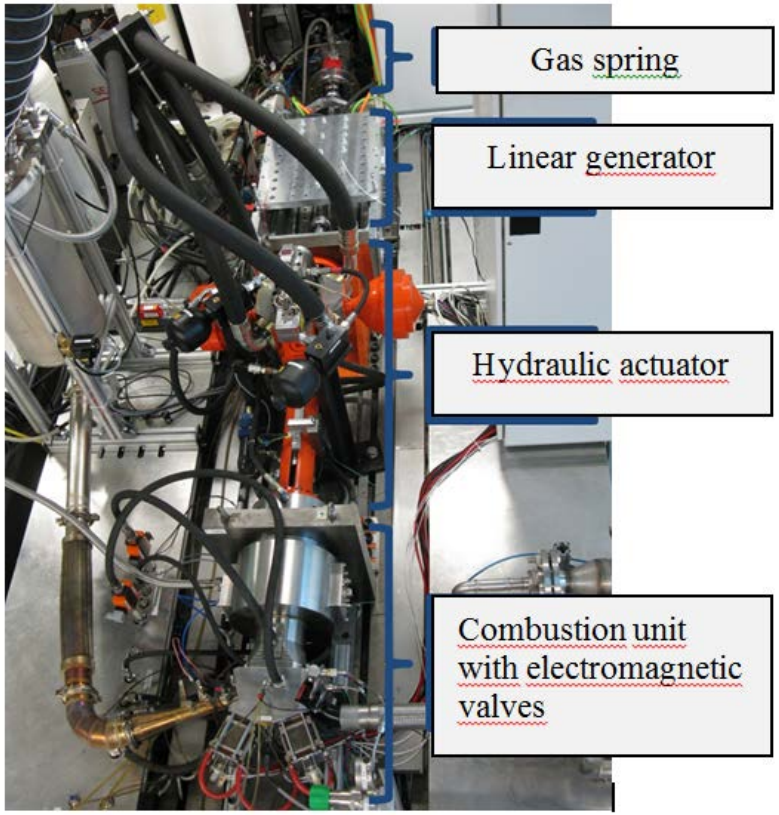
**Targets:**

- Reduced fuel consumption
- Higher efficiency
- Piston made of carbon
- Reduced friction
- Able to operate with different fuels

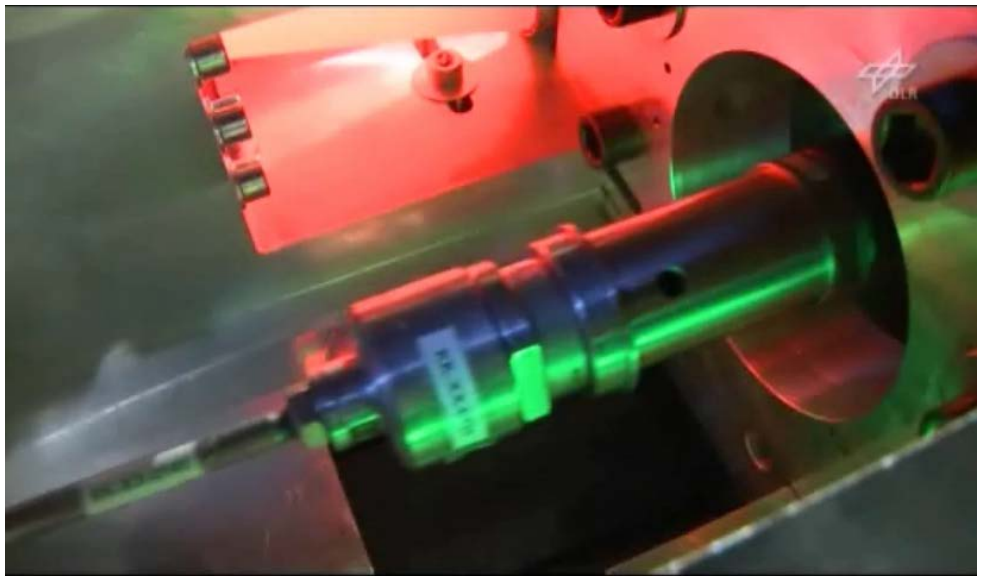



Carbon-Kolben

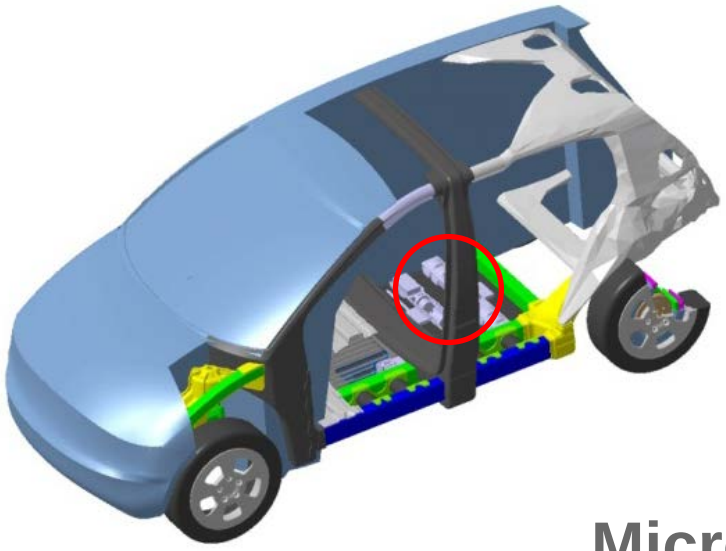
# Electric Energy Supply with the Free Piston Linear Generator




Test bench



In motion



# Micro Gas Turbine

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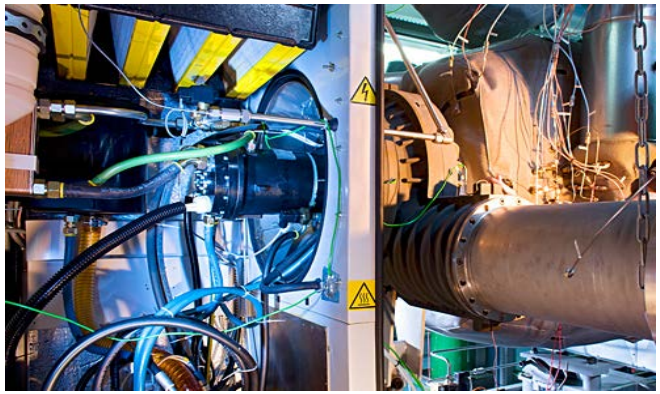
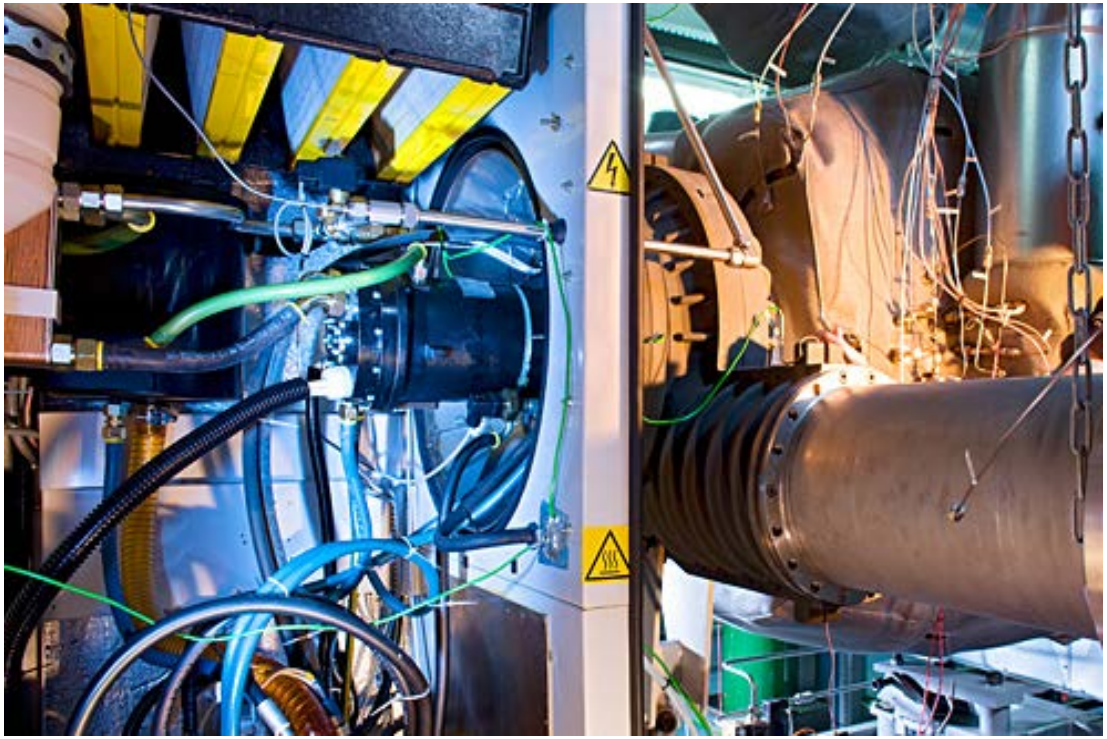
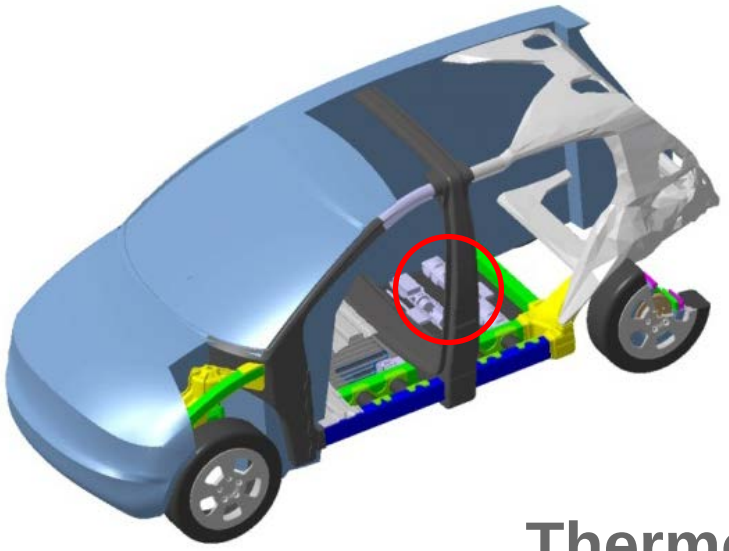


# Micro Gas Turbine



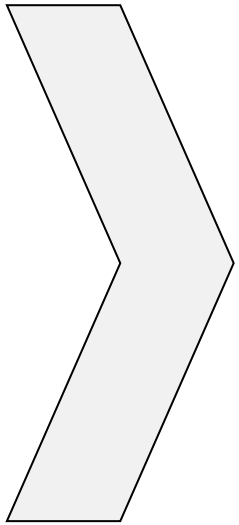
- Increasing the efficiency by thermal or thermoelectric recuperators

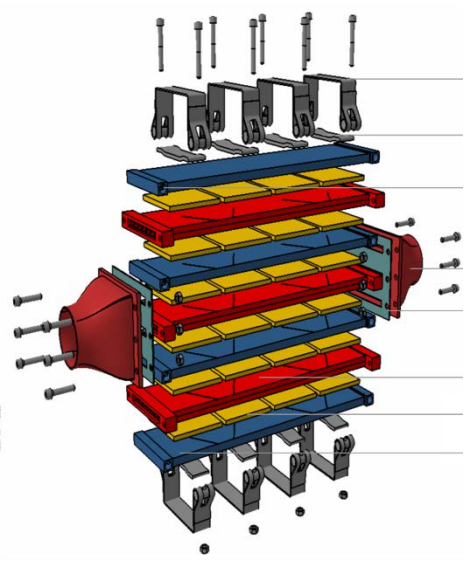


# Thermoelectric Energy Conversion

# Thermoelectric Energy Conversion

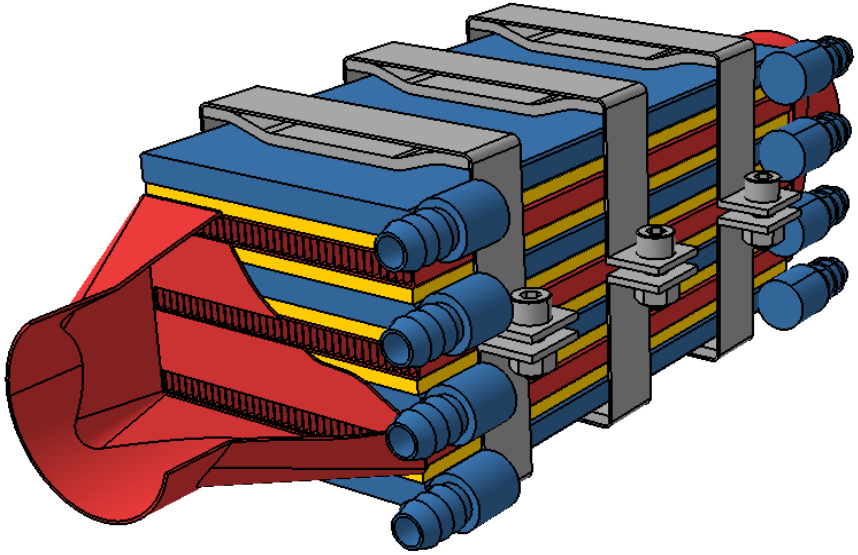
Quelle: Nasa





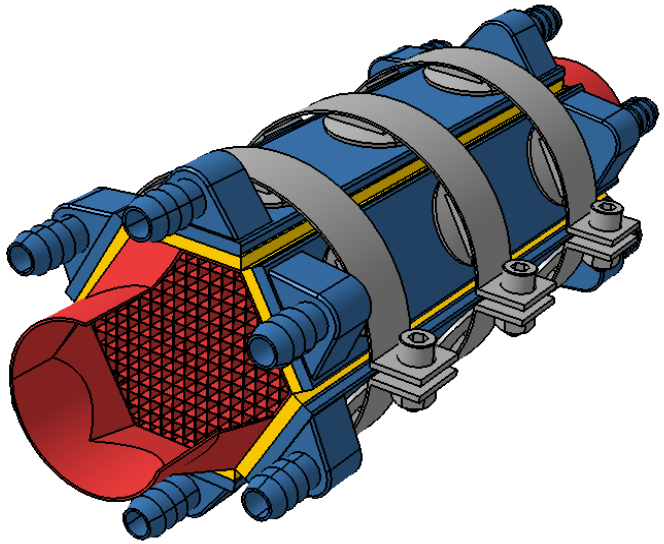
Utilisation of unused energy (waste heat)

# Detail Design of choosen TEG Variants



## stack architecture

First hardware demonstration in a cooperation between BMW and DLR in 2007 [1)]



## hexagon architecture

Inspired by a design of Hi-Z inc.[2)] and later on a design of Toyota[3)]


1) Treffinger, P. ; Häfele, C. ; Weiler, T. ; Eder, A. ; Richter, R. ; Mazar, B. : Energierückgewinnung durch Wandlung von Abwärme in Nutzenergie. In: *Innovative Fahrzeugantriebe 2008 : VDI-Berichte 2030* / VDI Wissensforum (Hrsg.). 2008

2) Bass, J. C. ; Elsner, N. B. ; Leavitt F. A. : *Performance of the 1 kW Thermoelectric Generator for Diesel Engines*. In: Proceedings of the 13th international conference on thermoelectrics (Kansas City 1994)

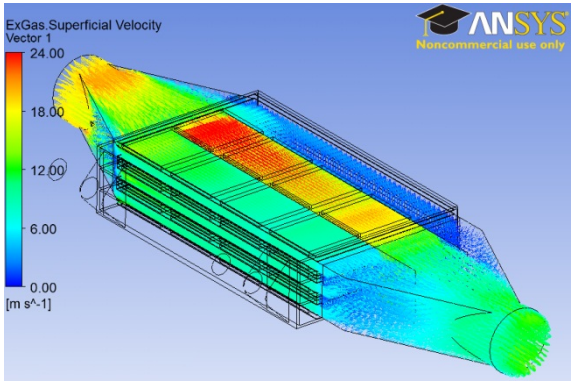
3) Schutzrecht DE 102005005077 A1 (2005-09-08). Shimoji. Pr.: 2004-029334 2004-02-05

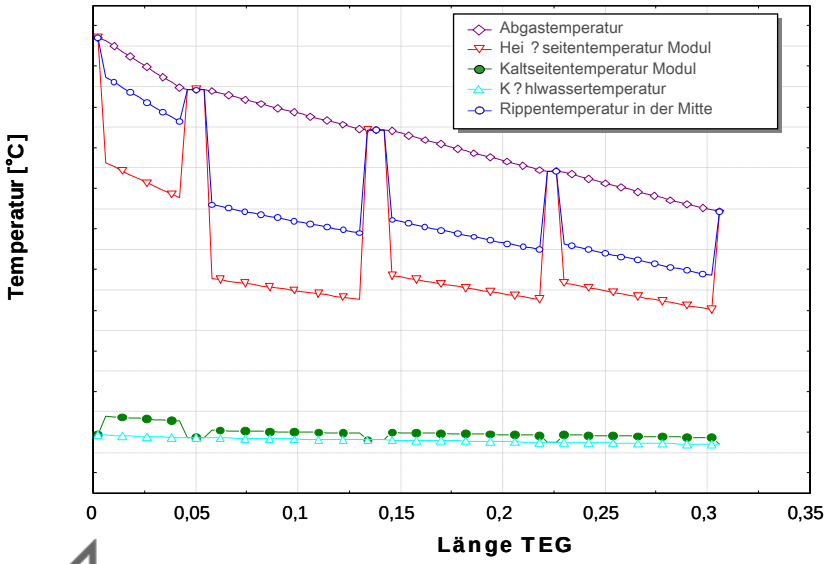

DLR

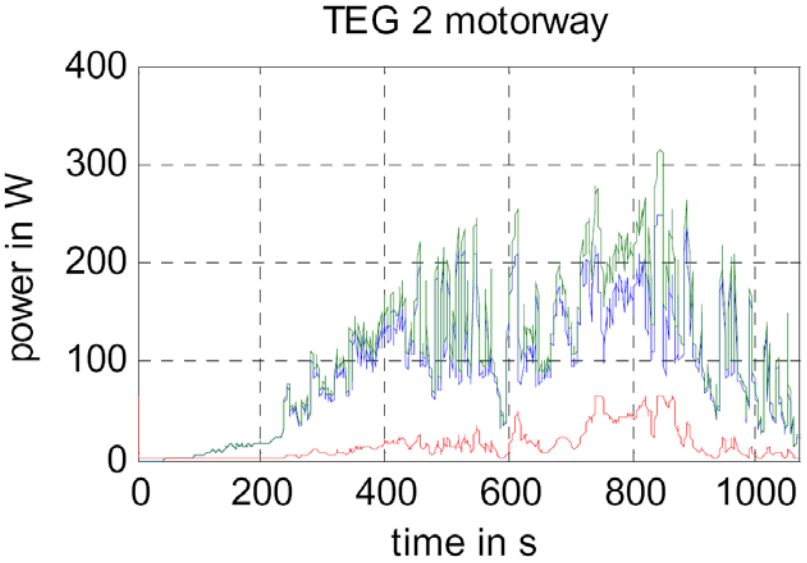
# Component Development

## computer based development/simulation

- stationaryTEG-modell in EES
- dynamic TEG-modell in MODELICA
- thermomechanic simulation in ANSYS
- flow simulation in ANSYS
- design and analysing of installation space with CATIA V5

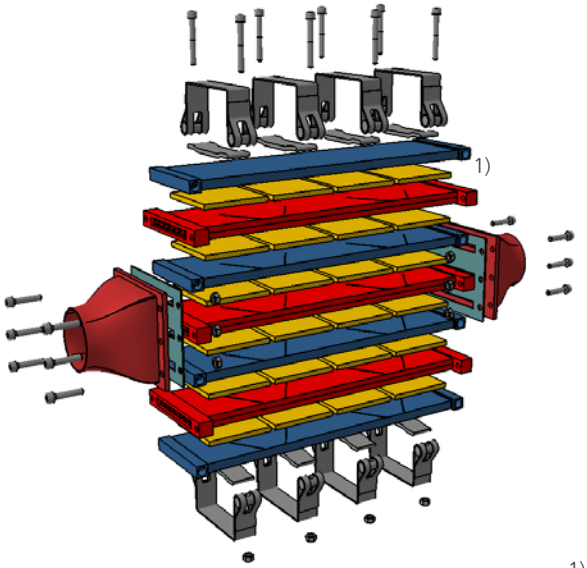


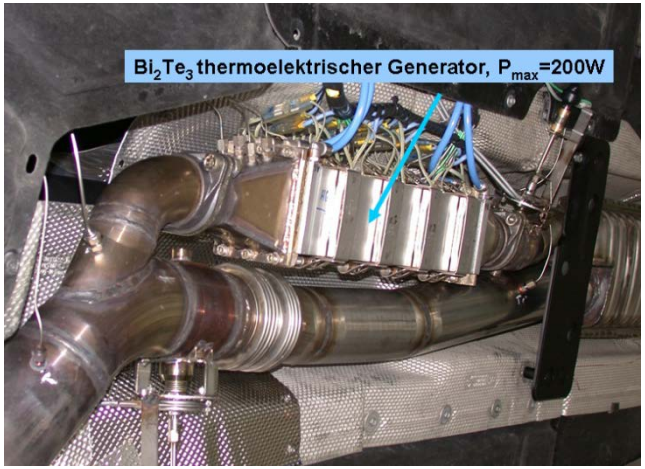

# Component Develpoment

- development, building and test of several prototypal TEG-generations in DLR-projects and industry-projects



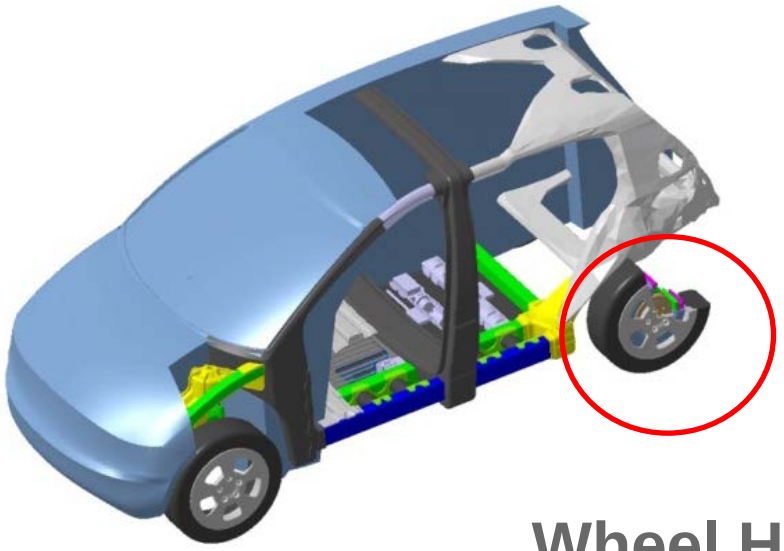

example: TEG-develpoment in cooperation with BMW

- Concept development
- Manufacturing of TEG-components in DLR-workshop (except modules)
- Assembly of TEG and initiation on hot gas test bench
- Integration in 535i US
- Test on DLR-roller dynamometer
- $P_{el}$~200W, >15000 test kilometers without fails



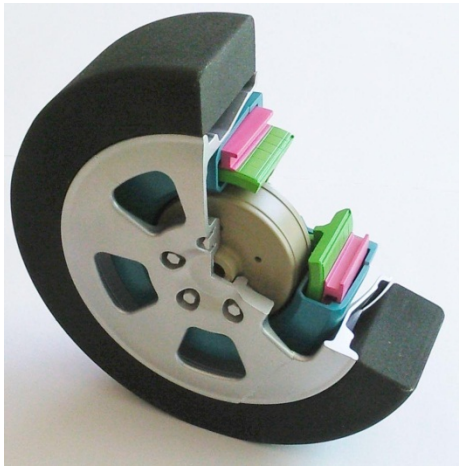

1) Treffinger P., Häfele Ch., Weiler T. DLR e.V. Stuttgart; Eder A., Richter R., Mazar B. BMW Group München: Energierückgewinnung durch Wandlung von Abwärme in Nutzenergie. 2008 VDI Tagung „Innovative Fahrzeugantriebe“, Dresden

# Thermoelectric Energy Conversion



# Wheel Hub Motors

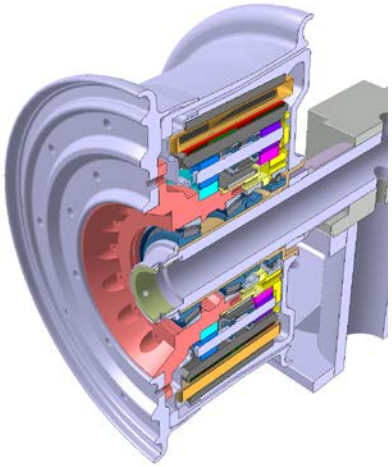
# Example: Wheel Hub Motor with integrated Gear

High integration of functions

# Detail Design of a Nose Wheel Drive

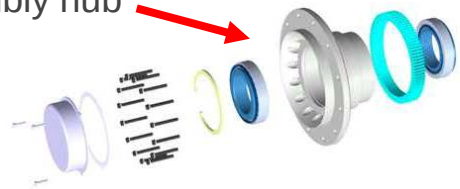
permanent magnet excited synchronous machine with single tooth winding



assembly stator

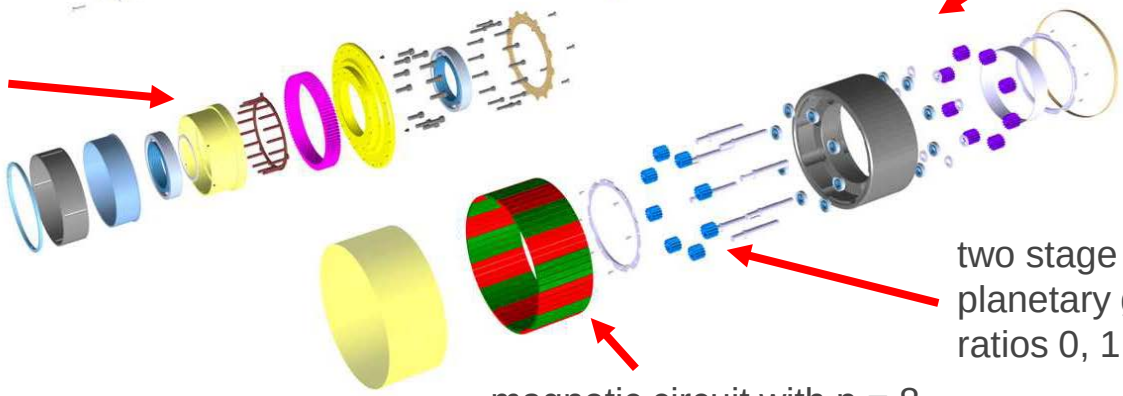
assembly rim

assembly hub



assembly rotor carries the planetary gears

assembly coupling shaft



two stage planetary gear with ratios 0, 1, 12

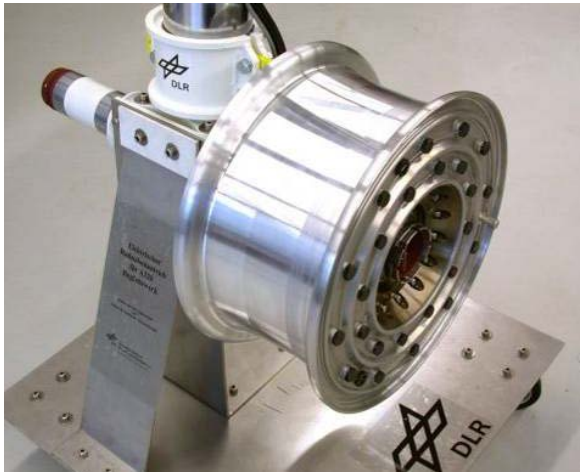
magnetic circuit with p = 8

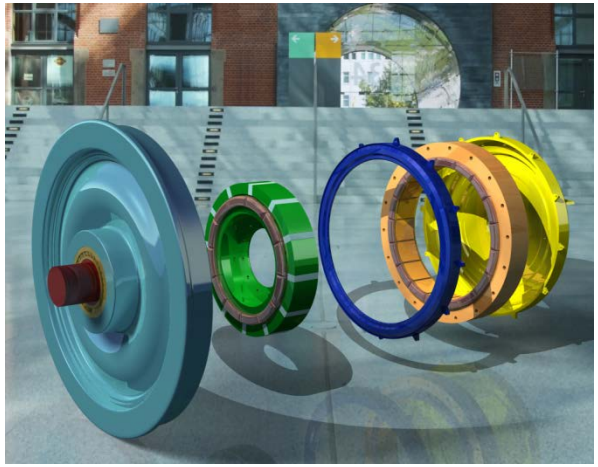
# Wheel Hub Motors

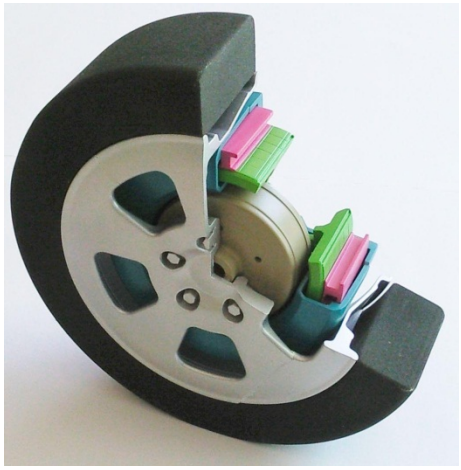
torque up to 11 kNm

speed up to 440 km/h

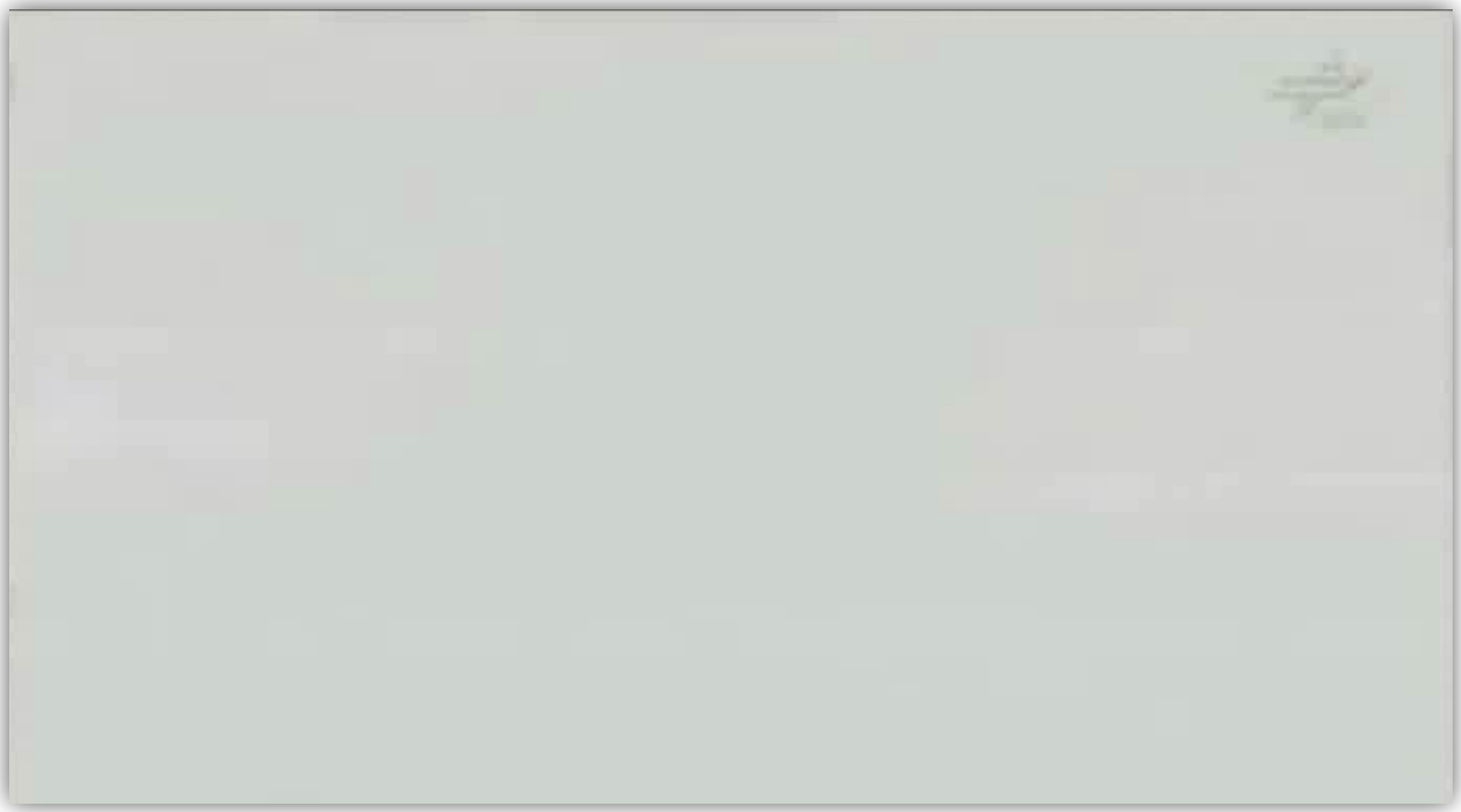
low cost, high quantities



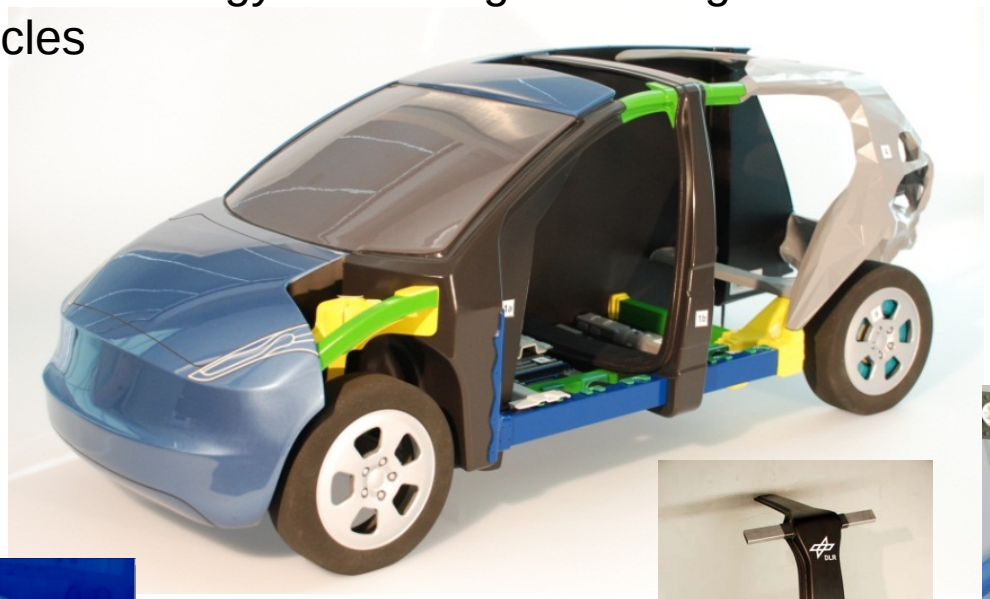


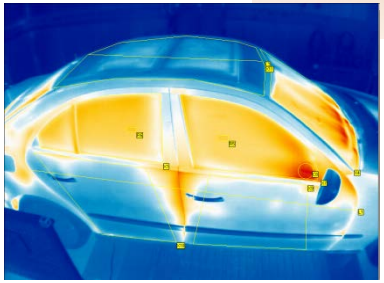
# Wheel Hub Motor with integrated Gear

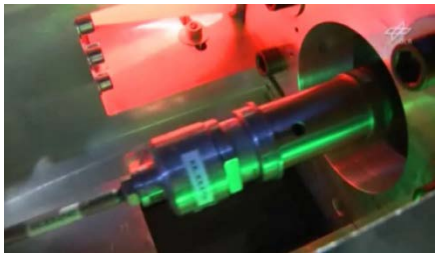


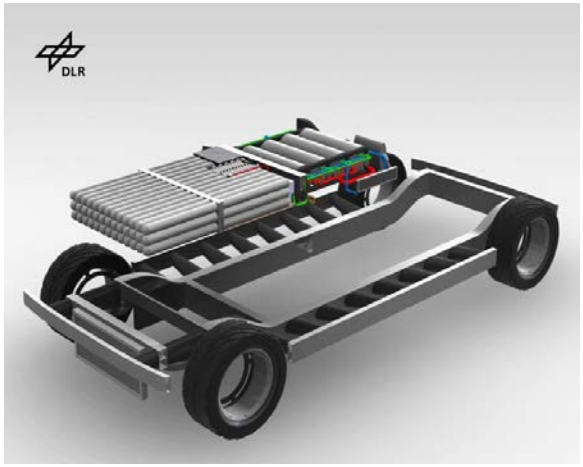
# Conclusion

- Knowlege for tomorrow is also based on innovative technologies coming from aerospace research
- Special examples of energy converting technologies could be used for future ecological vehicles







Deutsches Zentrum
für Luft- und Raumfahrt e.V.
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**Institute of Vehicle Concepts**

Thank you for your attention