

# **Fuel Cell Powered Airport Ground Support Equipment GSE**

**ELECTRIC VEHICLES LAND – SEA – AIR Conference**

**June 29th, 2011, Stuttgart**

**DLR-Institute of Vehicle Concepts  
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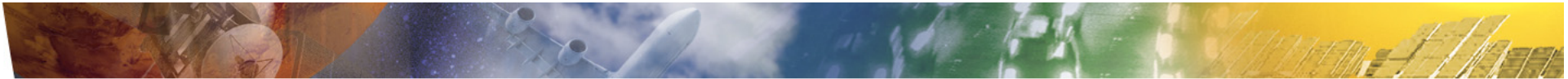
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in der Helmholtz-Gemeinschaft

# Vision

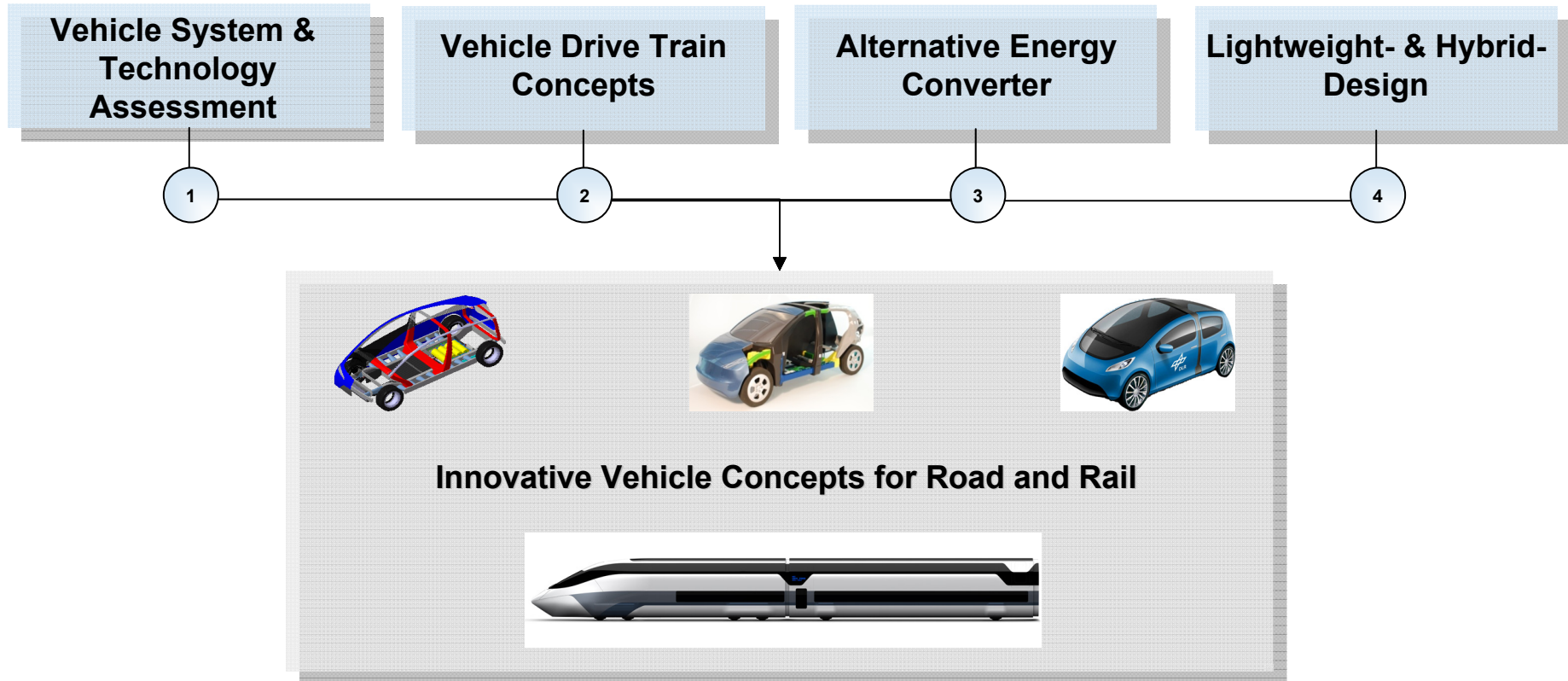
**Sustainable, Secure and Financeable  
„Individual Mobility“**



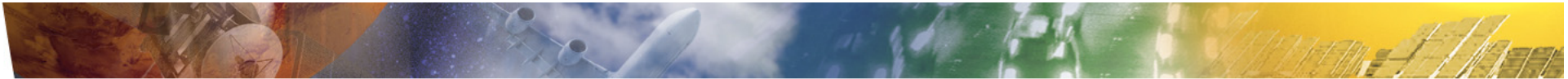
- ▶ Significant **Improved Useage of Energy Potentials** for Vehicle and Transport Tystems
- ▶ Breakthrough at **Emission- / CO<sub>2</sub>-Free or -Neutral Power Train Technologies**
- ▶ Increasing **Energy Efficiency of Transport**



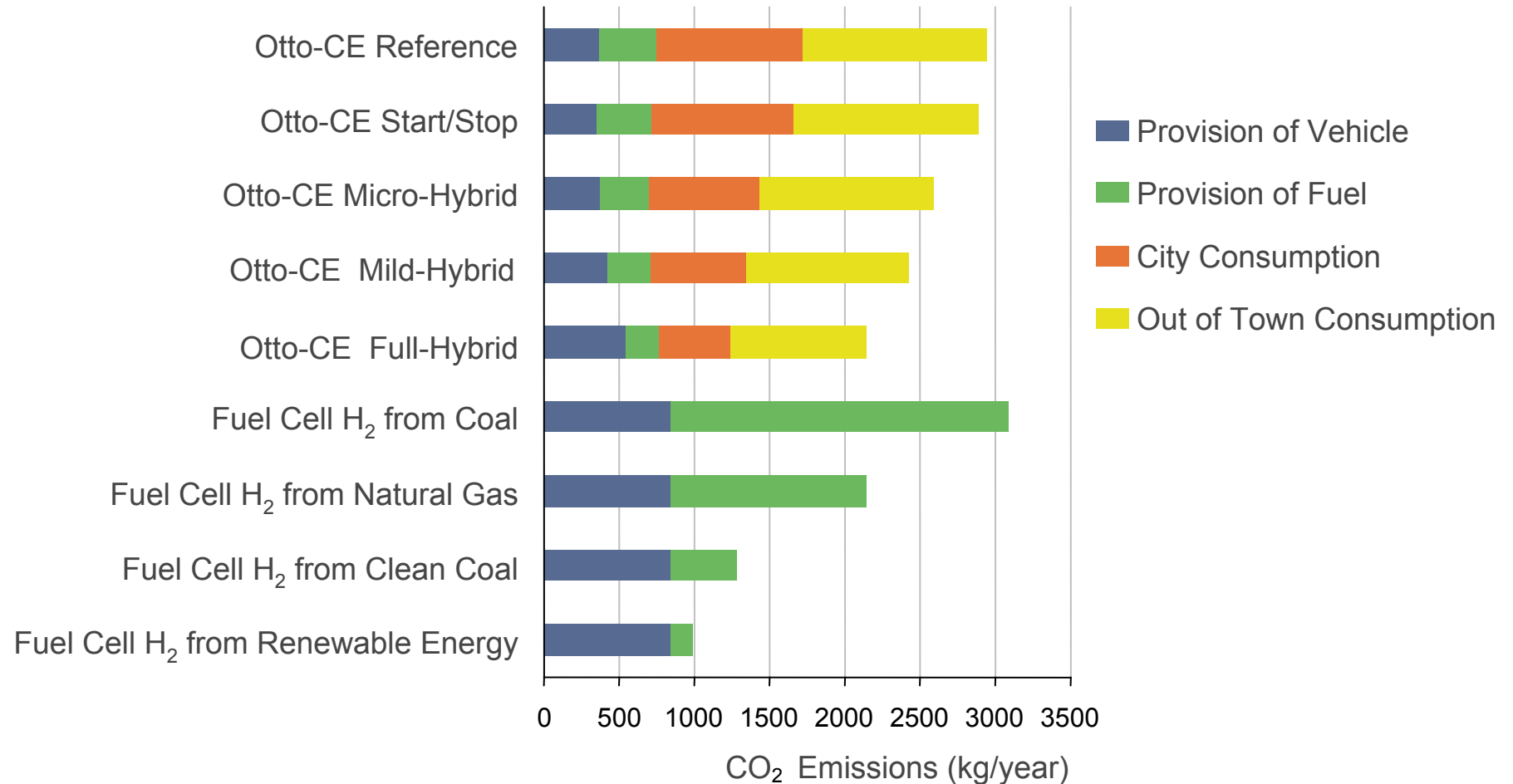
# The Fields of Research of the DLR-Institute FK



FK **designs** and **demonstrates** innovations for vehicle concepts and technologies of new transportation concepts adopted to the needs

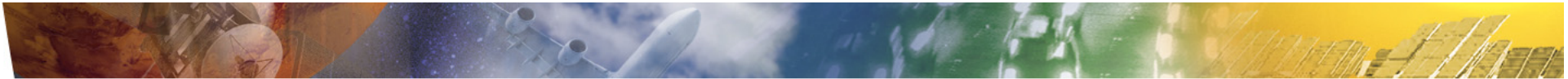


# CO<sub>2</sub> – Emissions of Hybride Drive Train Concepts compared to Fuel Cell Power Trains

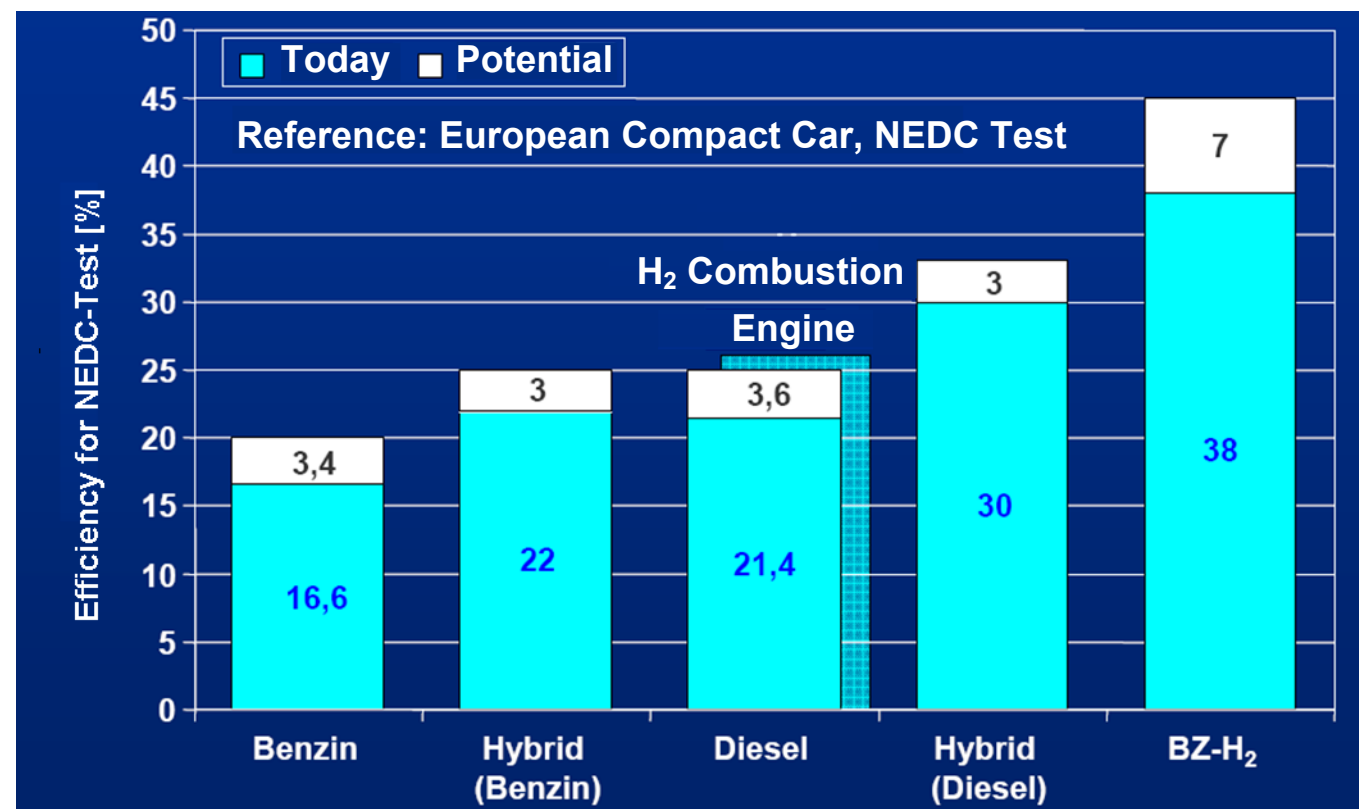


**CE: Combustion Engine**

Sources: DLR. R. Edwards, Well-To-Wheel Analysis, 2003. UBA-H2, Entwicklung einer Gesamtstrategie zur Einf. alternat. Kraftstoffe. Pehnt, Ganzheitliche Bilanzierung, 2002. Schweimer, Sachbilanz des Golf A4, Wolfsburg.

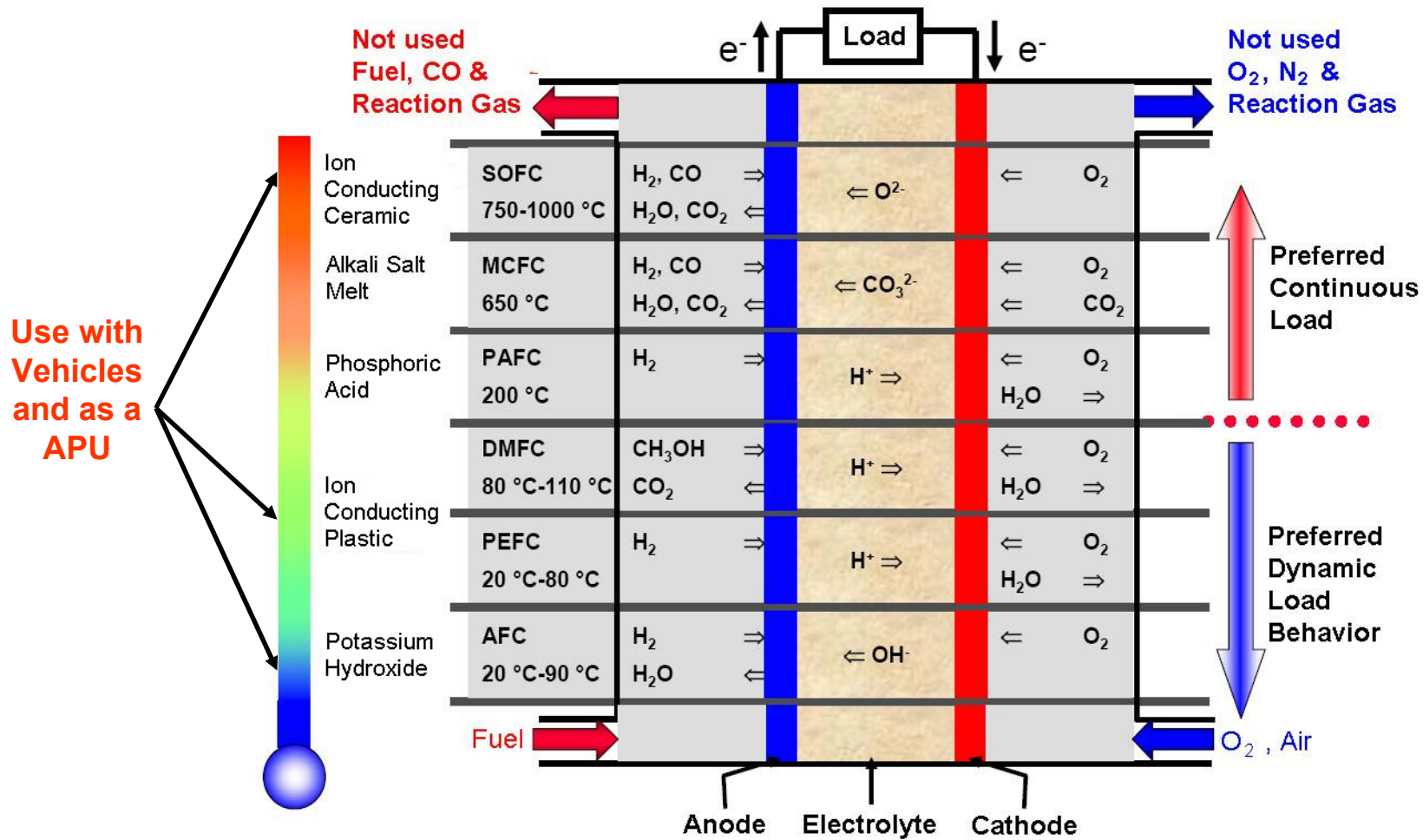


# Comparison of Power Trains Efficiencies and its Development Potentials with a Tank-To-Wheel-Look



**High Efficiency: Low Usage of Primary Energy Sources  
Over Compensation of Energy Losses during Hydrogen Production  
by High Fuel Cell System Efficiency**

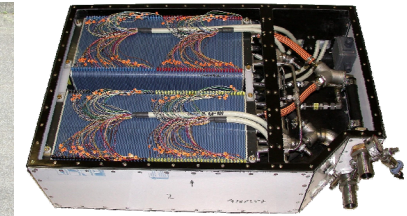
# Classification of Fuel Cell Technologies



# Fuel Cell System Development

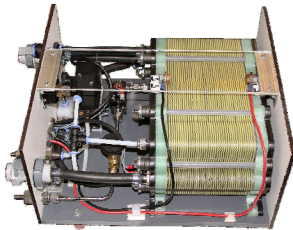
- Development platform and test beds for component manufacturers
- New system components
- System design and integration into vehicles
- Energy management strategy

## Road Vehicles



Project HyLite  
Hybrid Fuel Cell  
Vehicle

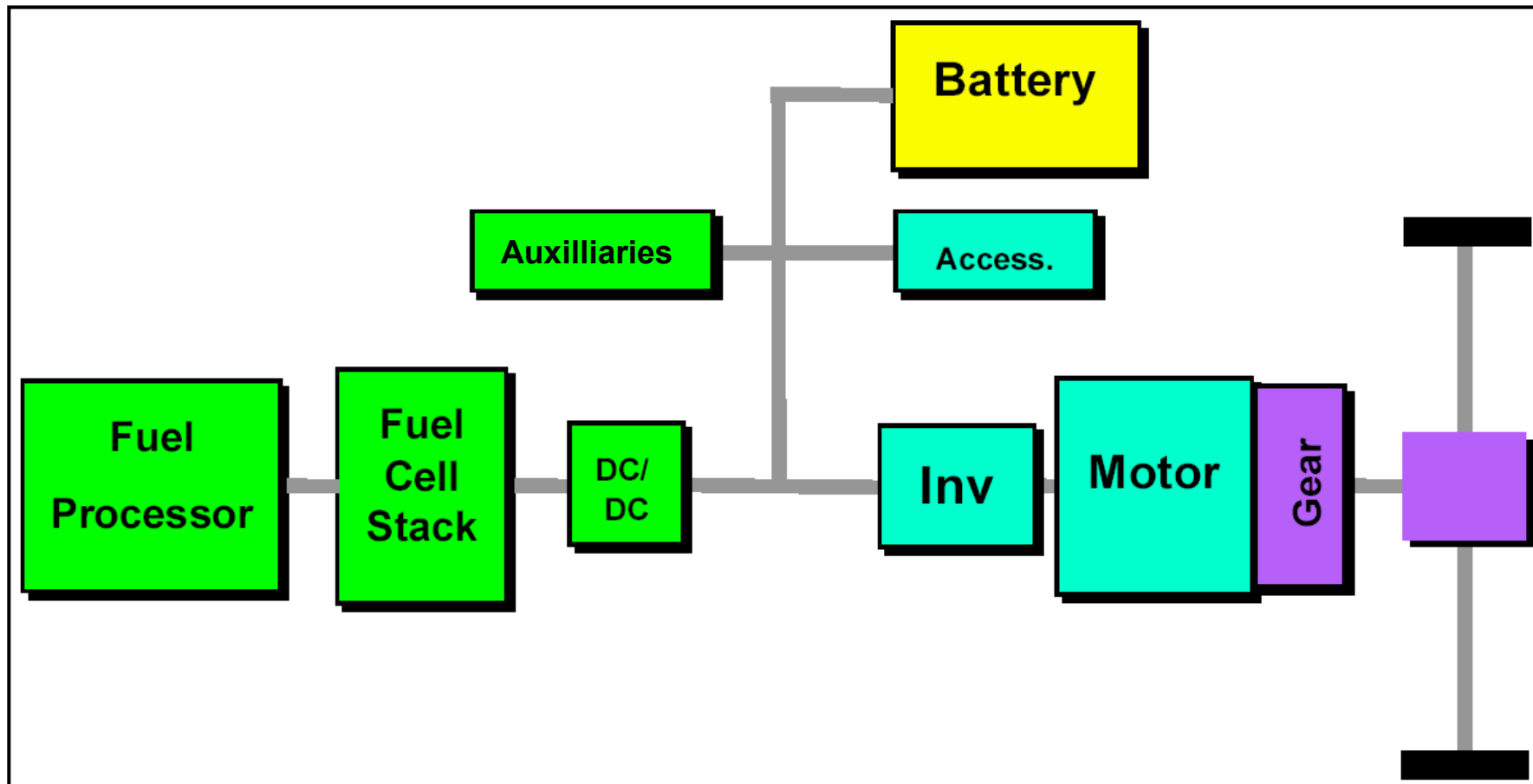
## Project Aprone-Luggage Pulling Machine



## Industrial Vehicles & Electrical Machines

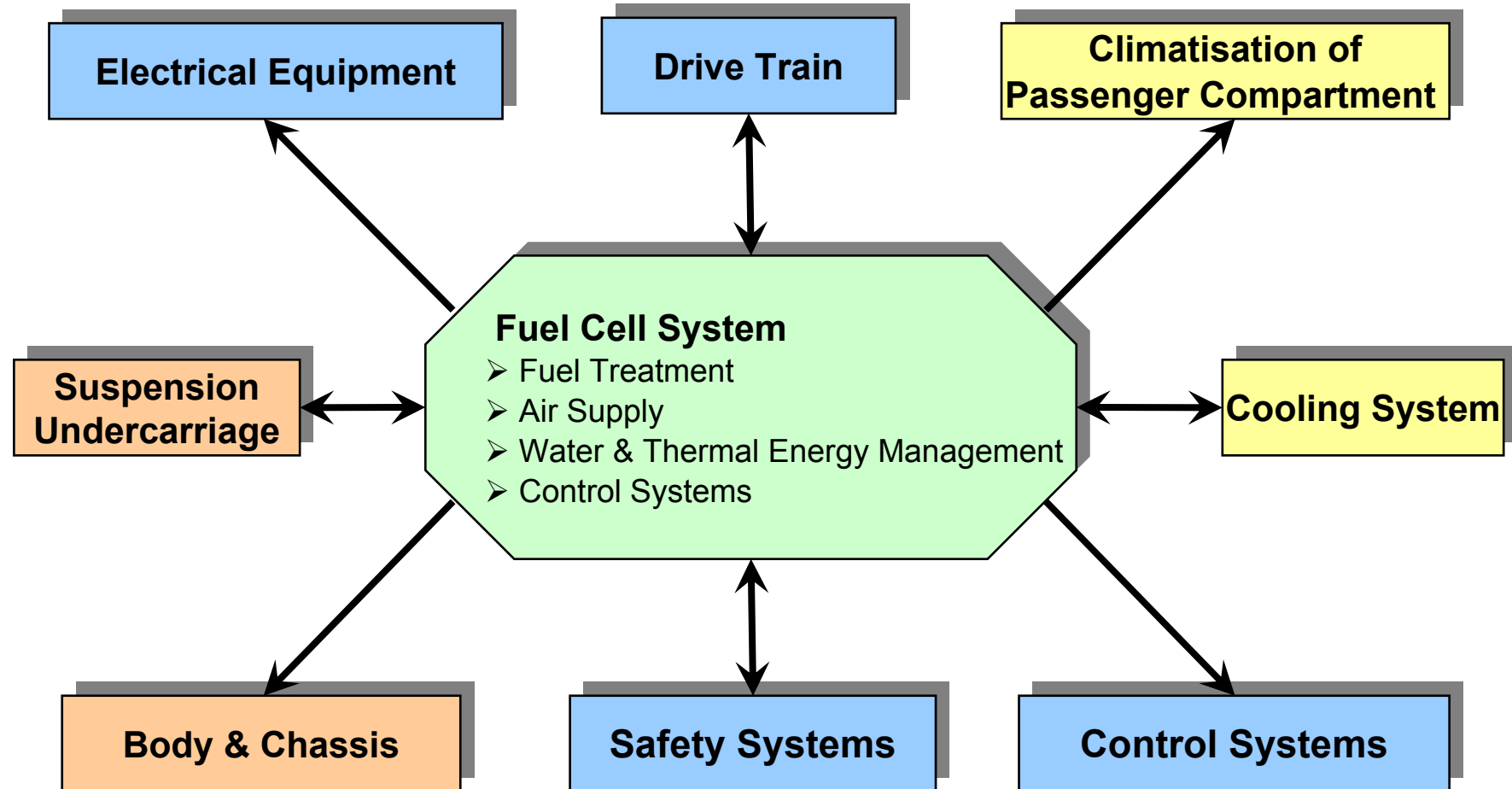
- „Minimal“ and rugged fuel cell system
- Air-cooled or liquid-cooled stacks
- No humidification
- Operation near to atmospheric pressure
- Modularization of the system

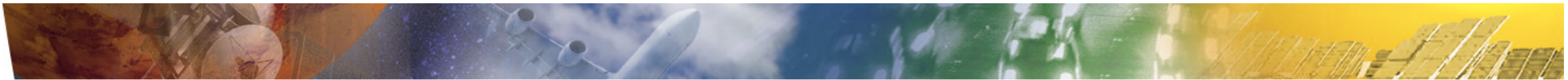
# Hybrid Power Train with Fuel Cell



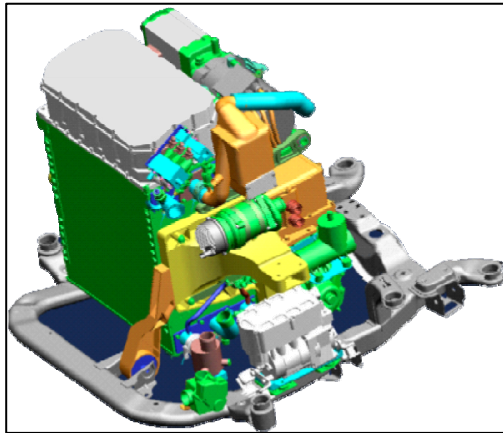


# Subsystems and Interaction of a Fuel Cell Vehicle





# Fuel Cell Vehicle – HydroGen3 liquid



## FC-System

- Stack
- Air Supply
- Thermal Management
- Water Management
- Power Electronics

„Startup“-Battery  
DC/DC-Converter



Elektric Power  
Train

Fuel  
Storage

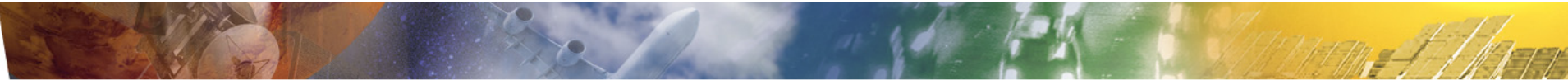
Bildquellen: R. v. Helmholtz, Adam Opel AG.



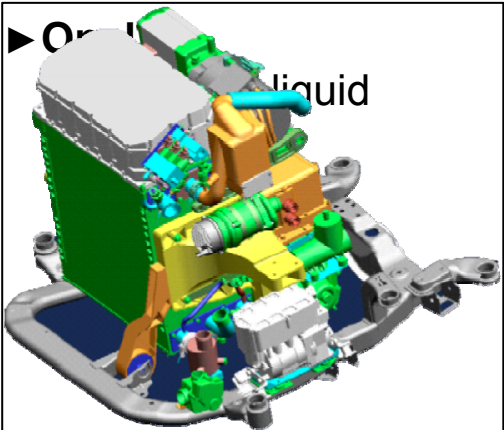
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Institute of Vehicle Concepts

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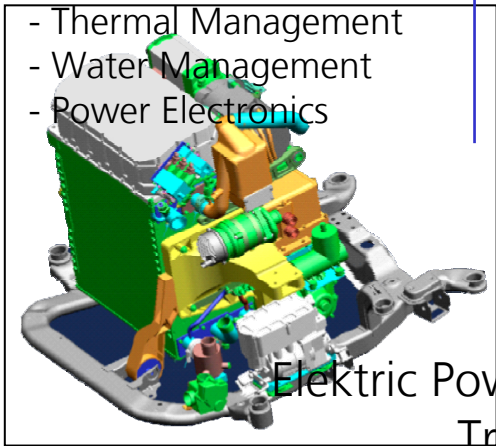


# Fuel Cell Vehicle – HydroGen3 liquid



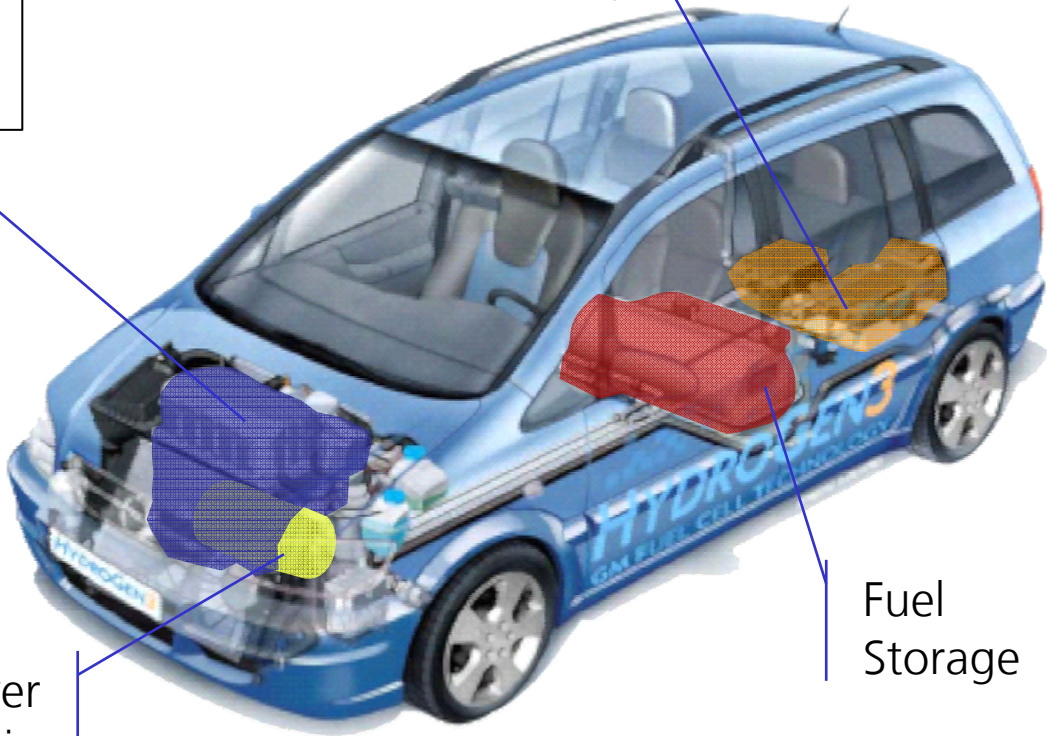
## FC-System

- Stack
- Air Supply
- Thermal Management
- Water Management
- Power Electronics



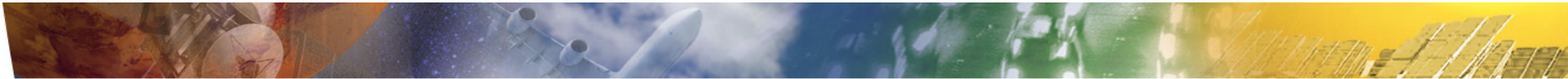
Elektric Power Train

„Startup“-Battery  
DC/DC-Converter

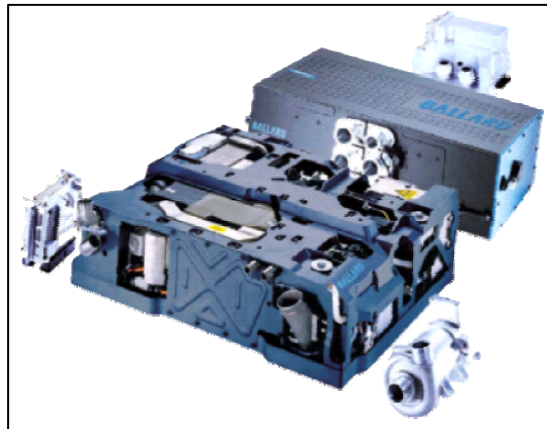


Fuel Storage

Bildquellen: R. v. Helmholtz, Adam Opel AG.



# Fuel Cell Vehicle – DaimlerChrysler F-Cell



## Hy-80

- 68 kW
- 220 l
- 220 kg

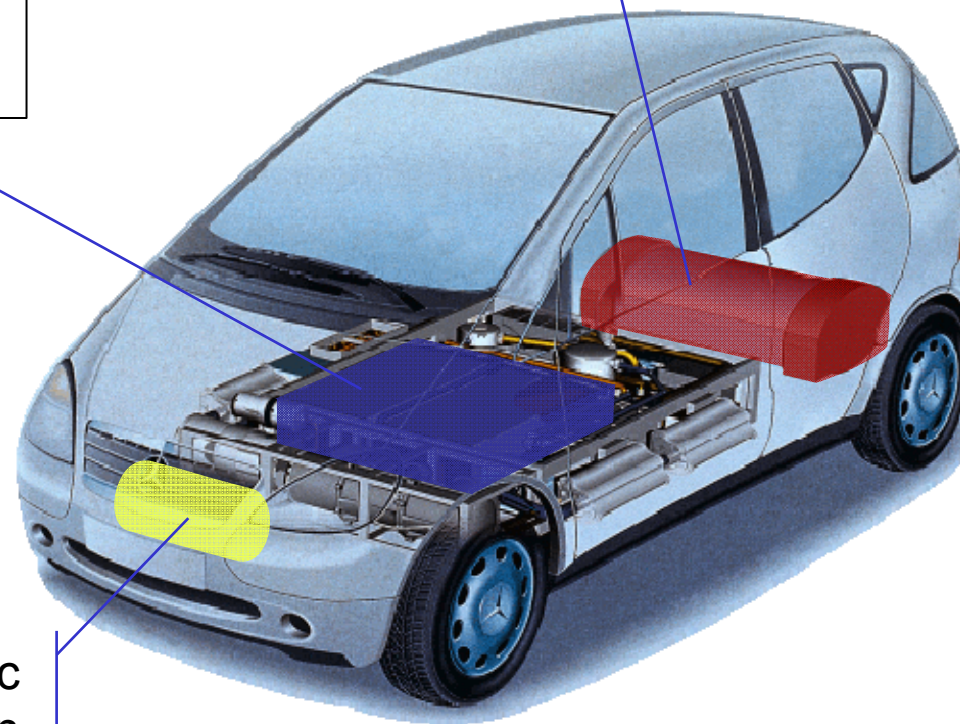
Bildquellen: DaimlerChrysler AG und A. Martin, Ballard.

## BZ-System

- Stack
- Air Supply
- Thermal Management
- Water Management

Fuel Storage

Electric Power Train



# Fuel Cell Vehicles

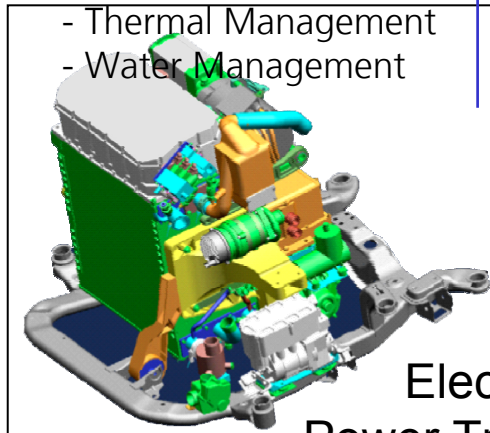
## ► Opel

HydroGen3 liquid



BZ-System

- Stack
- Air Supply
- Thermal Management
- Water Management

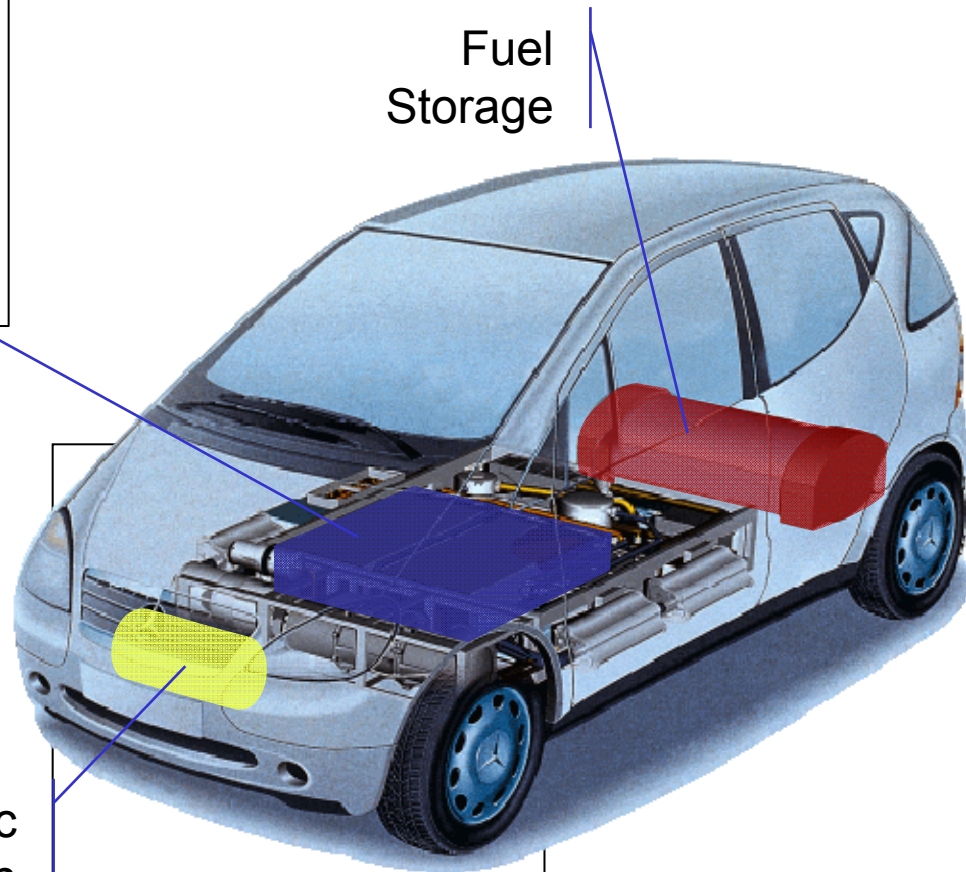


Electric Power Train

## ► DaimlerChrysler

F-Cell

Fuel Storage



Bildquellen: Adam Opel AG, DaimlerChrysler AG und A. Martin, Ballard.



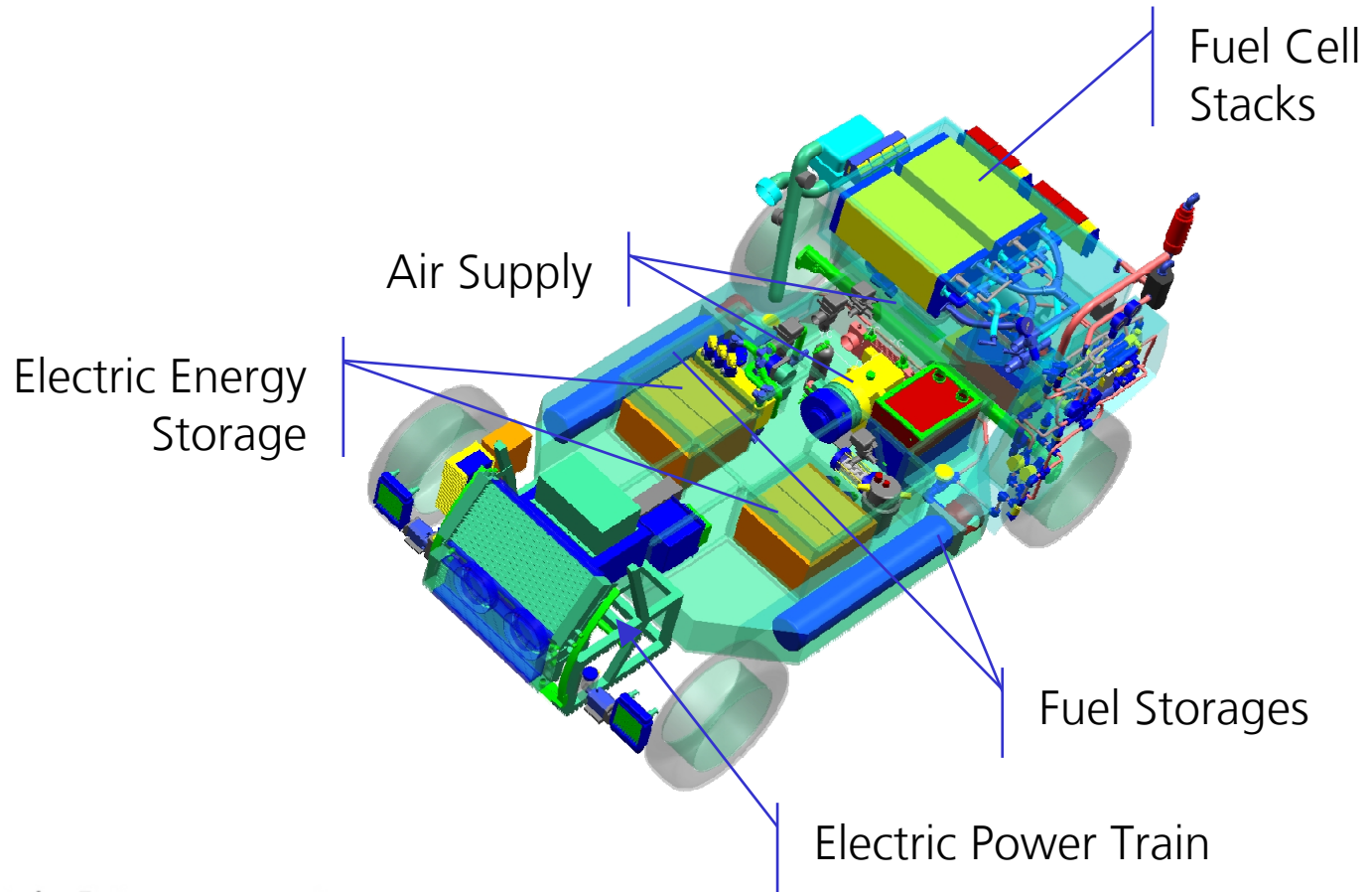
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# Fuel Cell Hybrid Vehicle HyLite<sup>®</sup> DLR



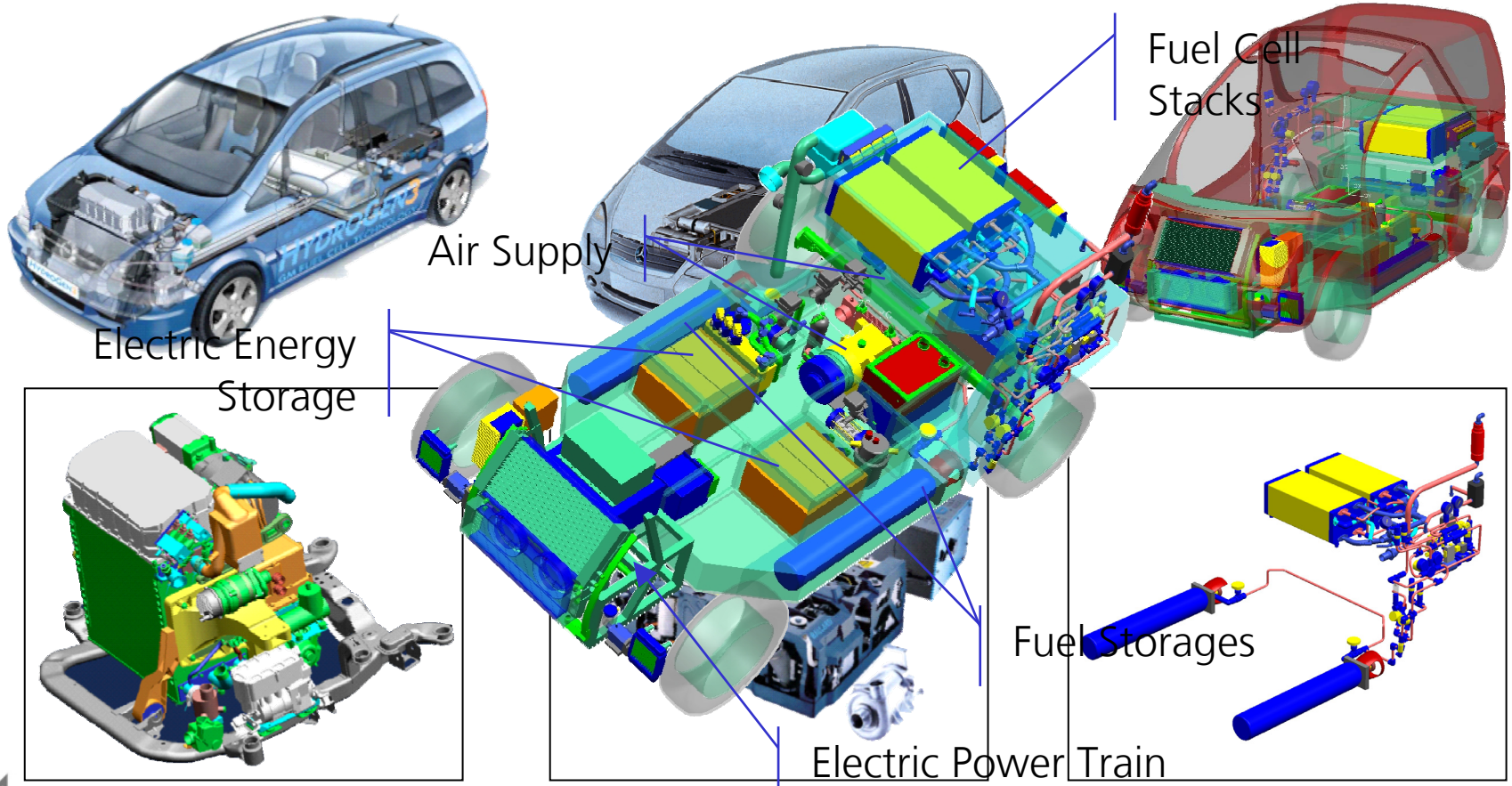
# Fuel Cell Vehicles



► Opel  
HydroGen3 liquid

► DaimlerChrysler  
F-Cell

► DaimlerChrysler  
HyLite



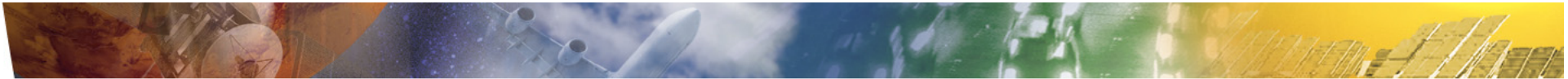
Bildquellen: Adam Opel AG, DaimlerChrysler AG



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in der Helmholtz-Gemeinschaft

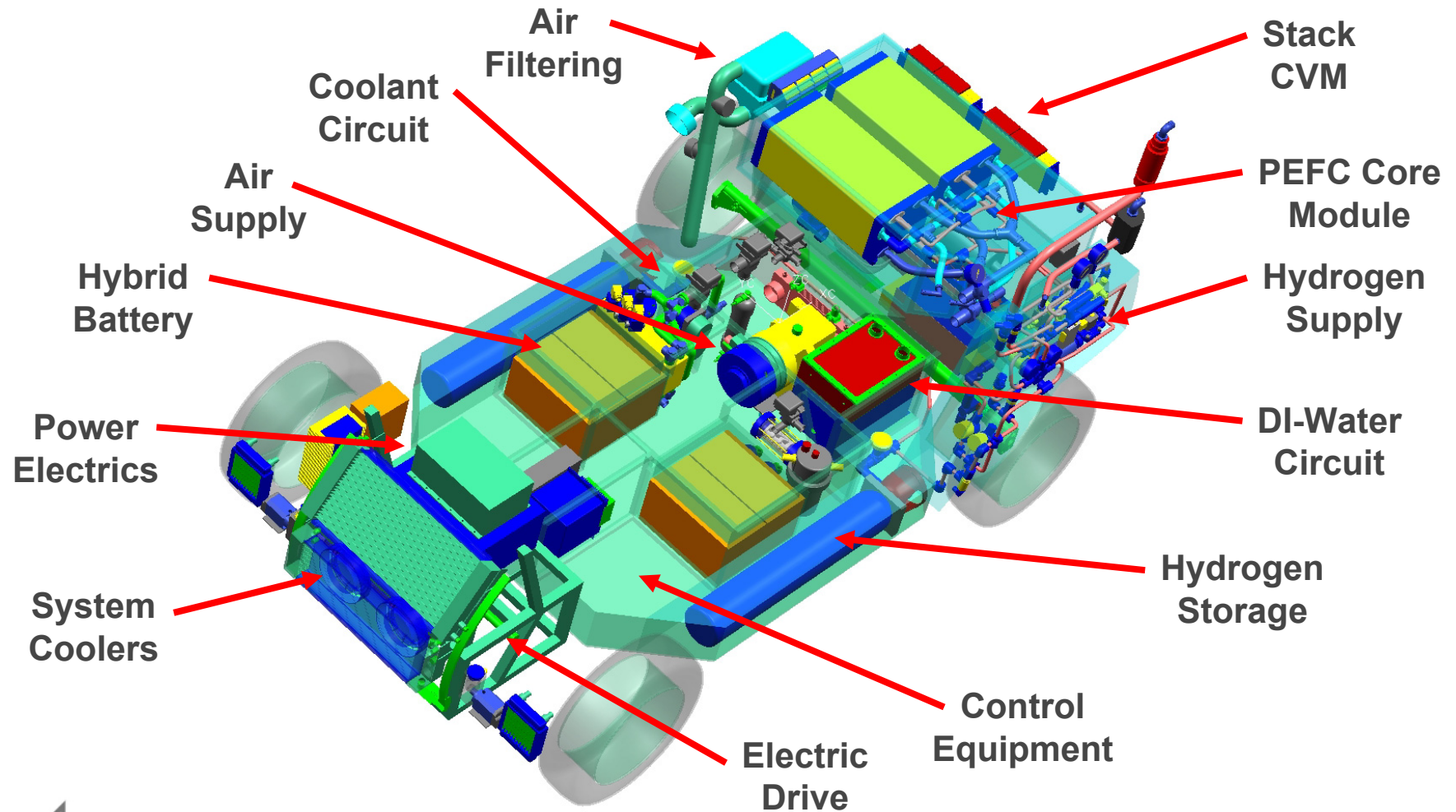
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# HyLite<sup>®</sup> Fuel Cell System Package

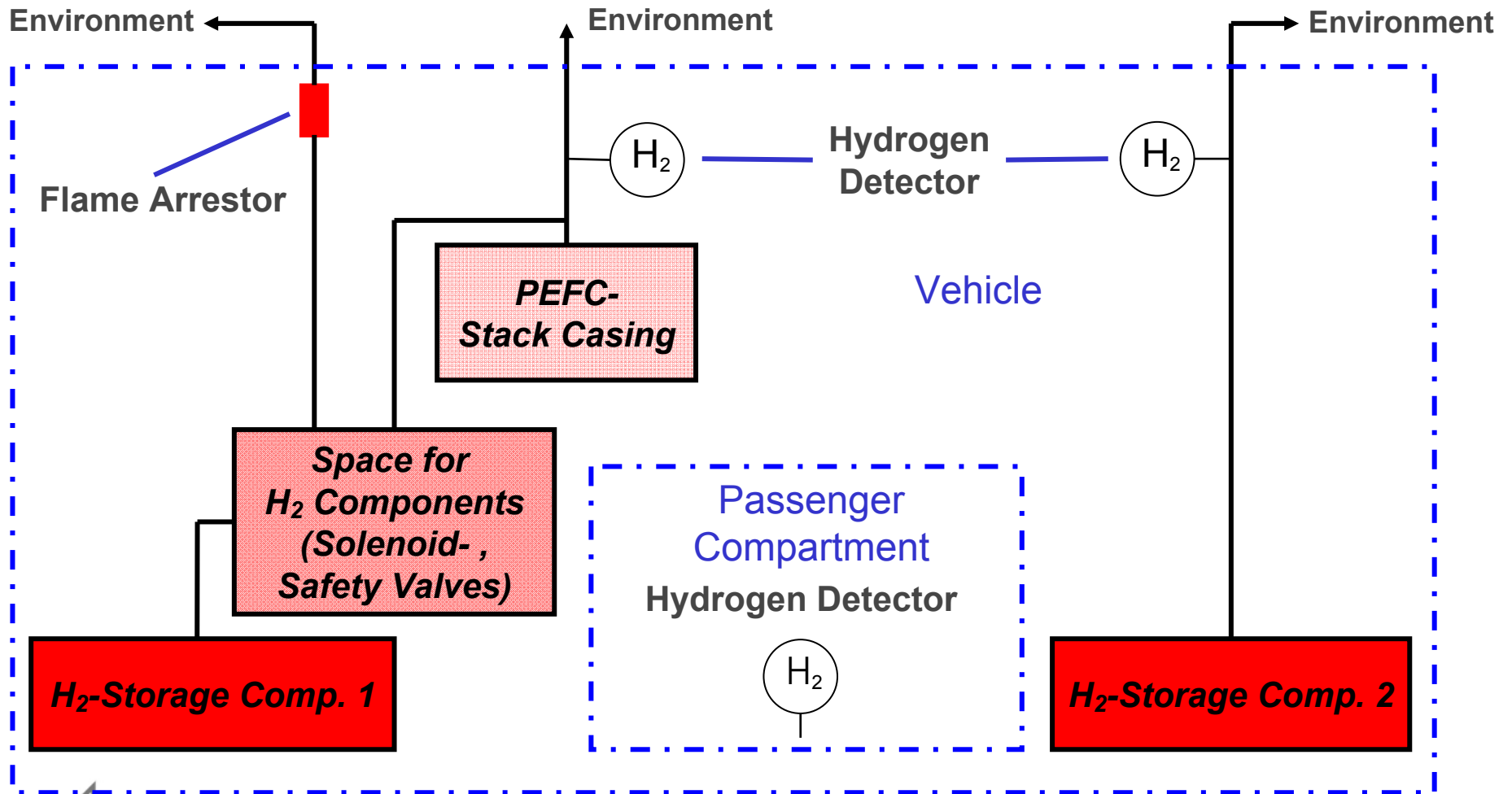
## Detailed View into the PEFC System Package





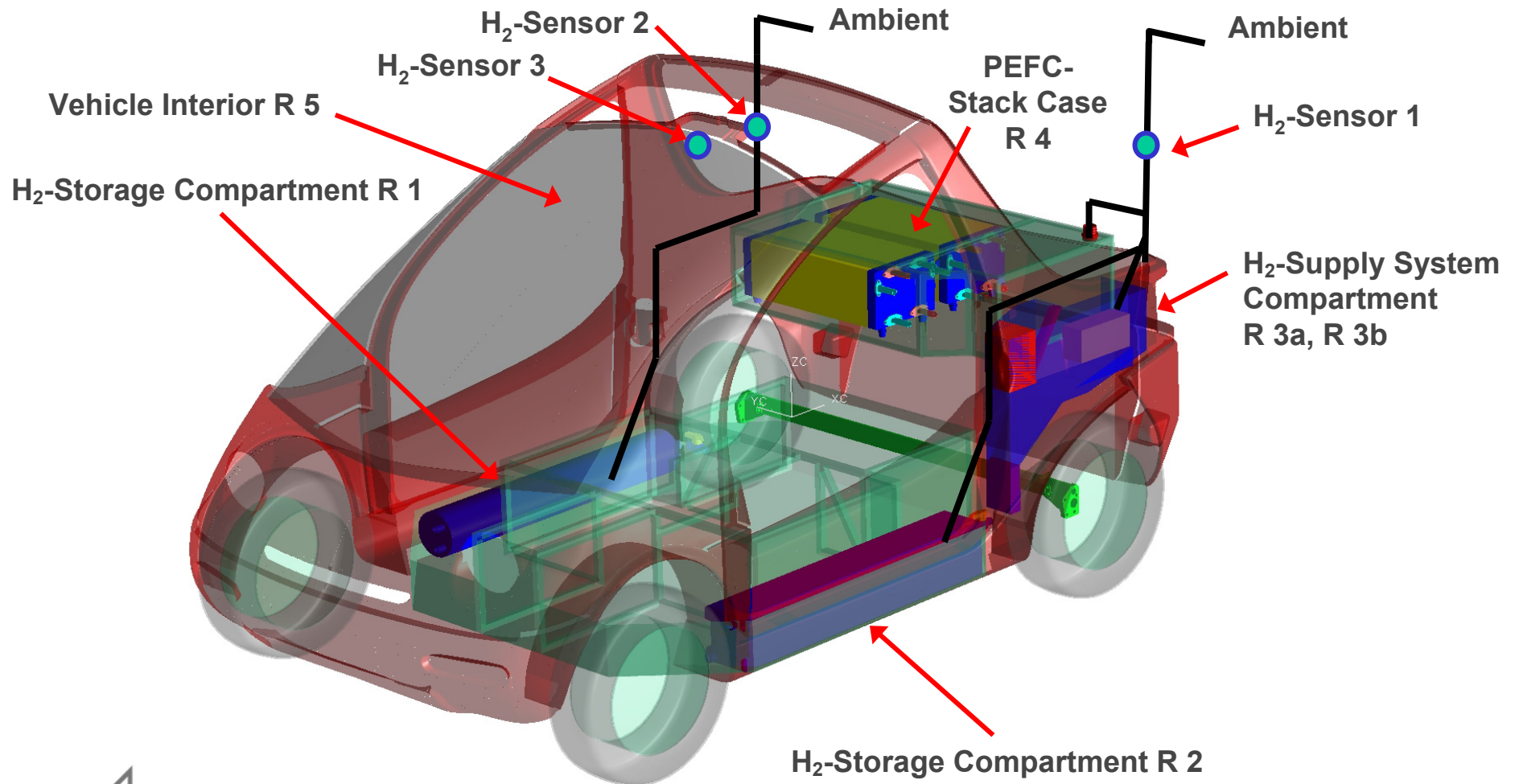
# HyLite<sup>®</sup> Fuel Cell System Package

## Hydrogen Safety Concept Design for the Vehicle



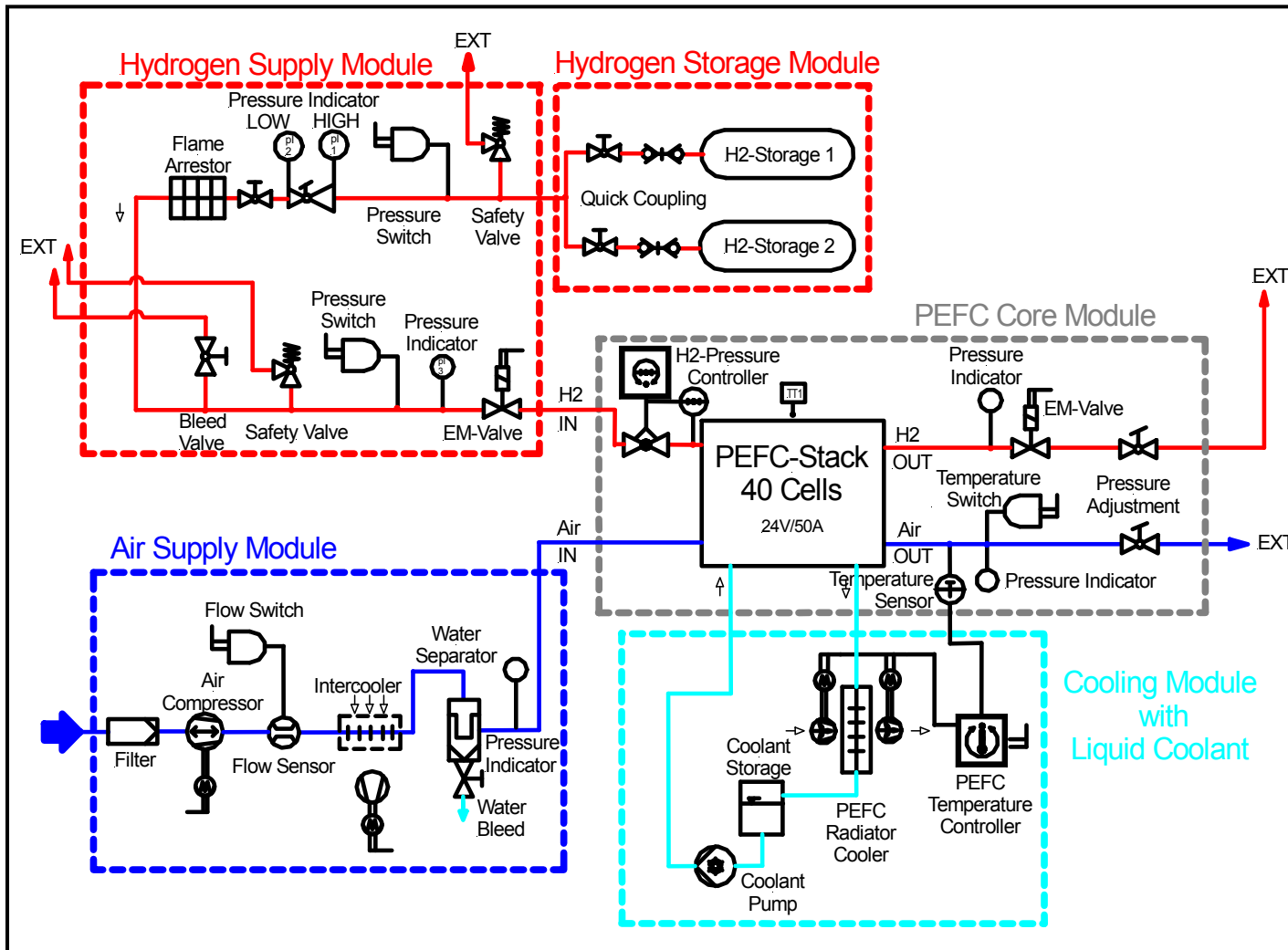
# HyLite<sup>®</sup> Fuel Cell System Package

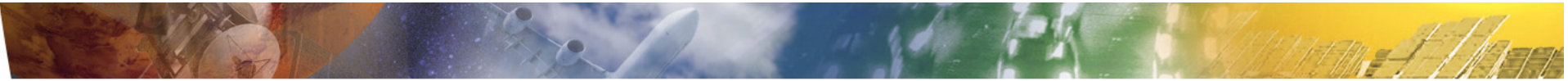
## Realization of the Hydrogen Safety Concept



# Modular PEFC Systems

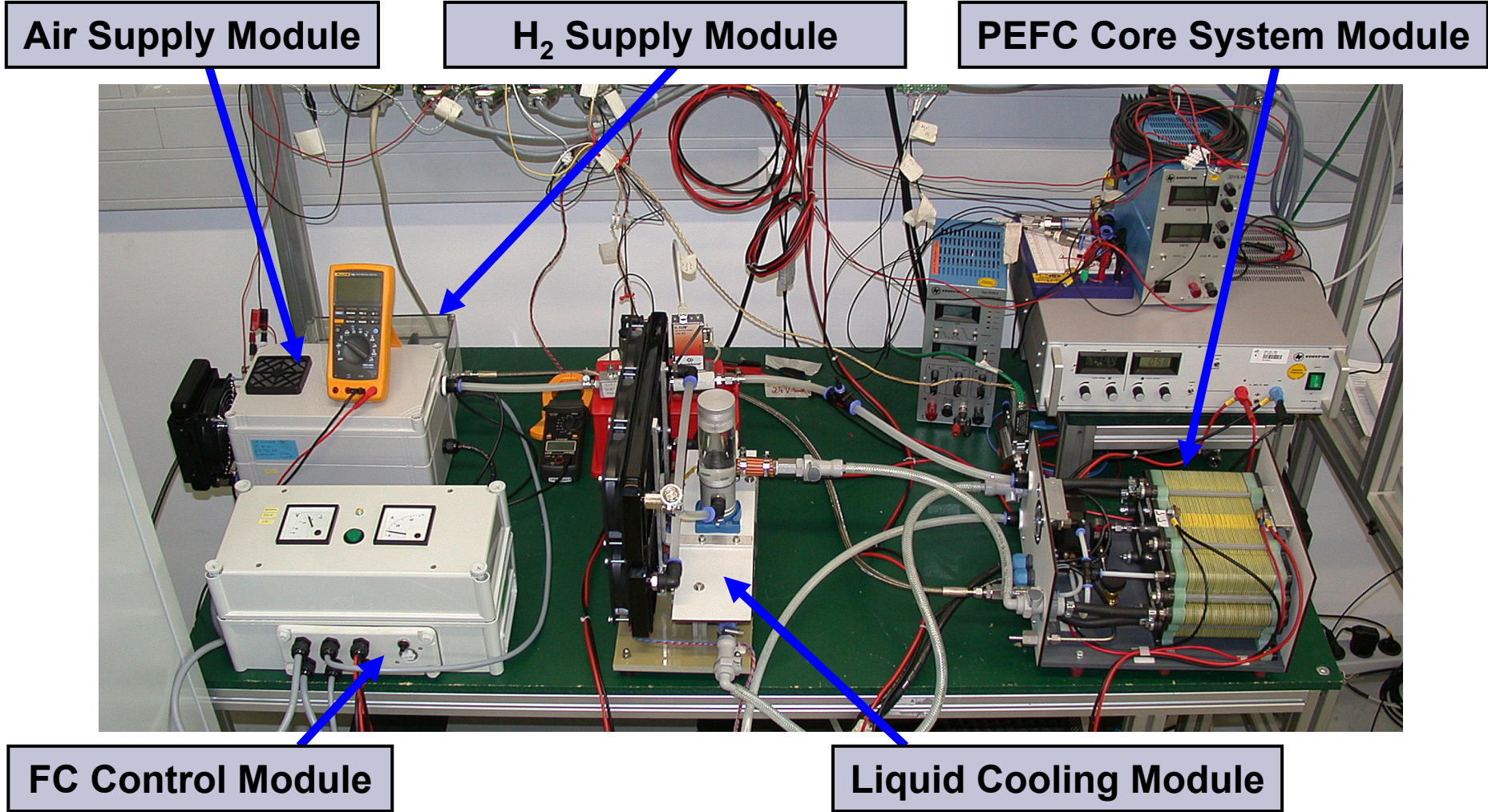
## P&I-Diagram of a Water-Cooled PEFC-System

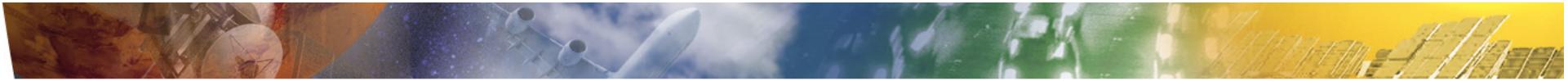




# SMALL VEHICLES WITH FUEL CELL POWER SUPPLY

## Modular 1,2 kW<sub>e</sub> PEFC system with fluid cooling circuit





# Modular PEFC Systems

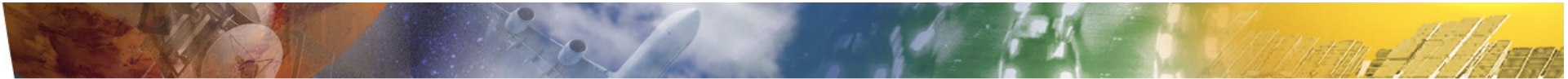
## System-Modularization and Standardization

**Modularization with system assembly made of 4 – 6 compact subsystems:**

- Hydrogen storage module
- Hydrogen supply module
- Air supply module
- PEFC system core module
- Cooling module
- Control & power adaptation module

**Standardization by non-interchangeable interconnections**

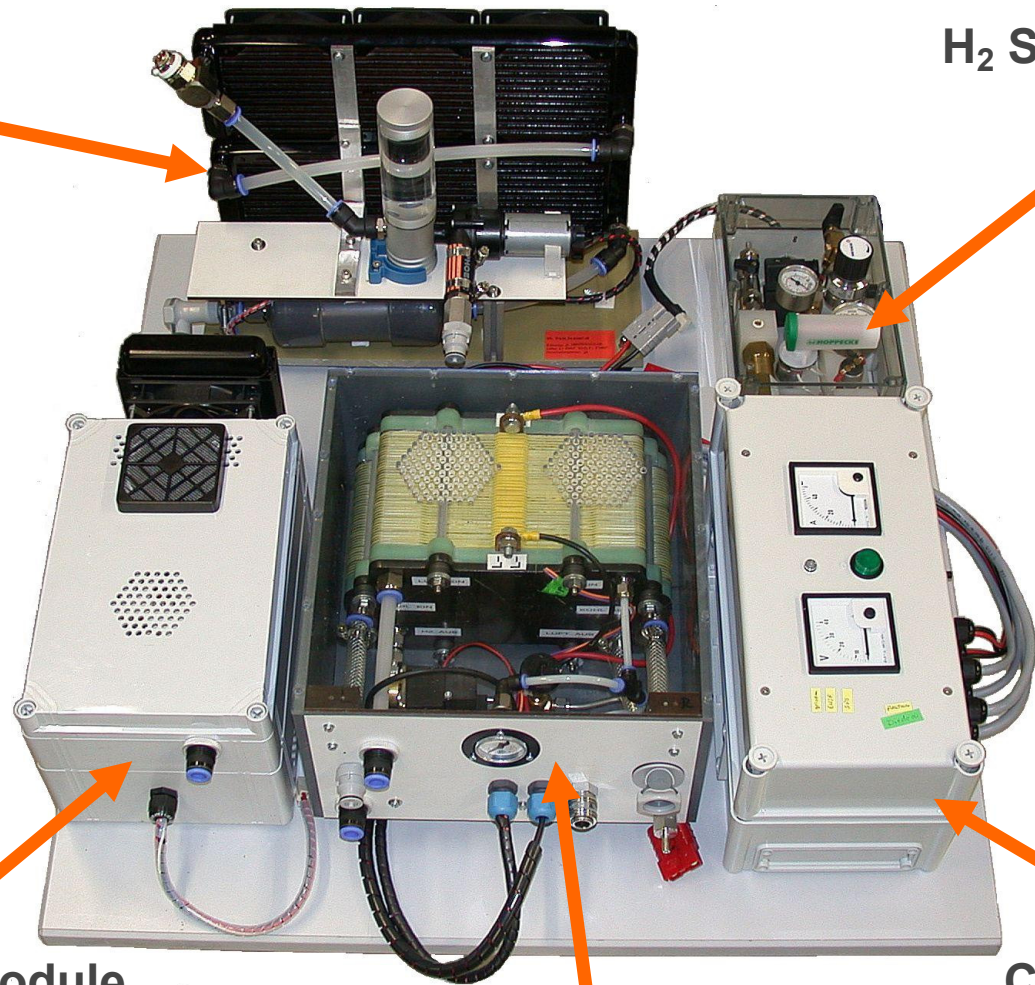
- Gas/ liquid interconnection piping and tubing
- Control signal cabling
- Power cabling



# Modular DLR- PEFC-System Concept with High Degree of Package Freedom for the Vehicle Integration

Cooling Module

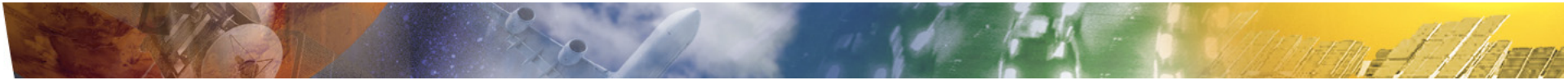
H<sub>2</sub> Supply Module



Air Supply Module

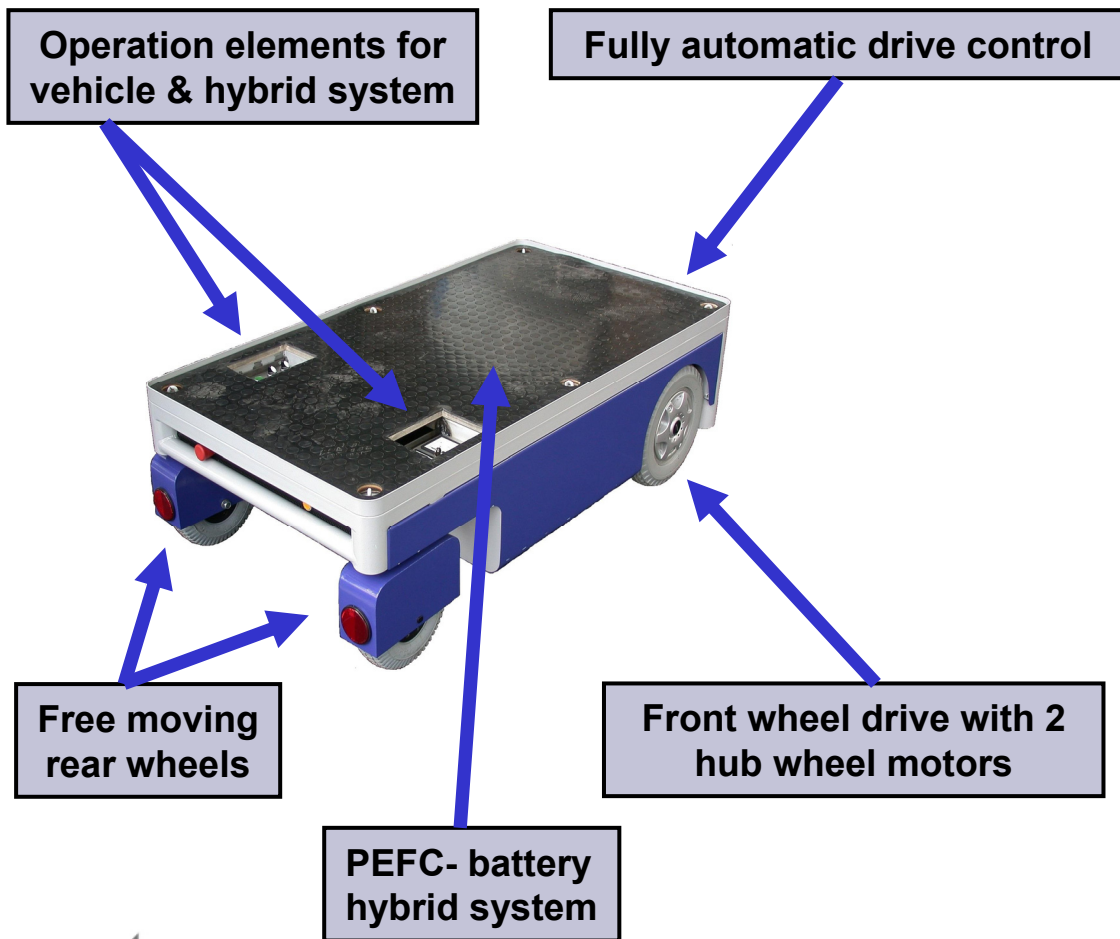
PEFC Cor System Module

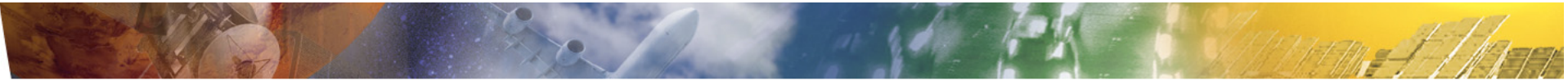
Control Module



# SMALL VEHICLES WITH PEFC POWER TRAIN

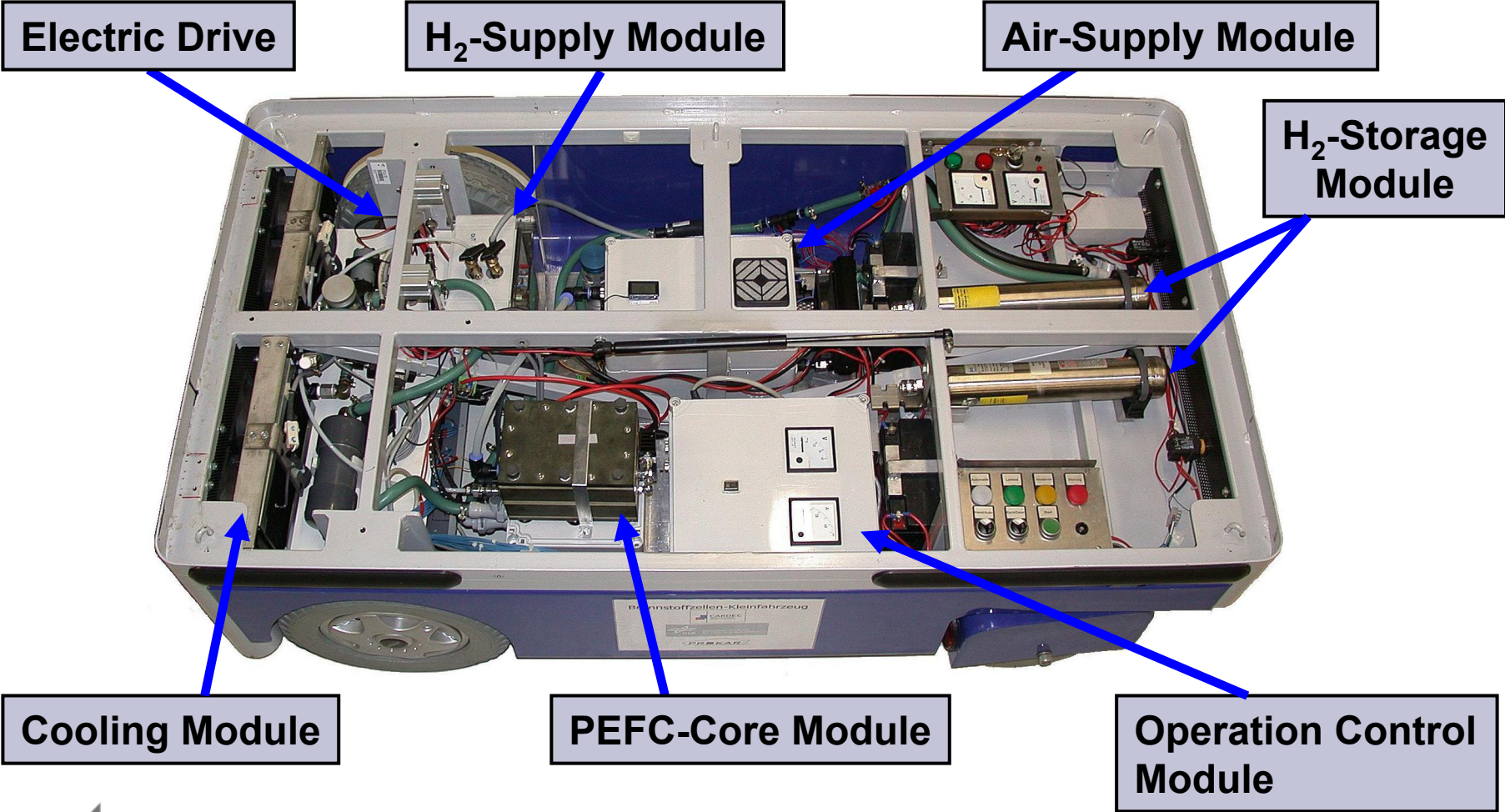
Automated Transportation Vehicle ATV with PEFC hybrid power train for a vehicle weight of about 100 kg and max. 400 kg of load



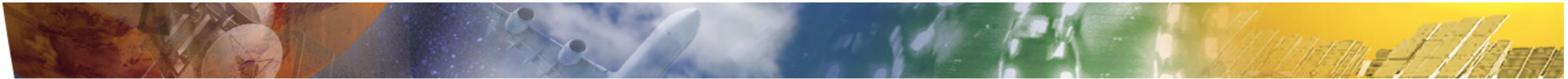


# SMALL VEHICLES WITH PEFC POWER TRAIN

Small transportation vehicle with modular 0,5 kW H<sub>2</sub>-PEFC system





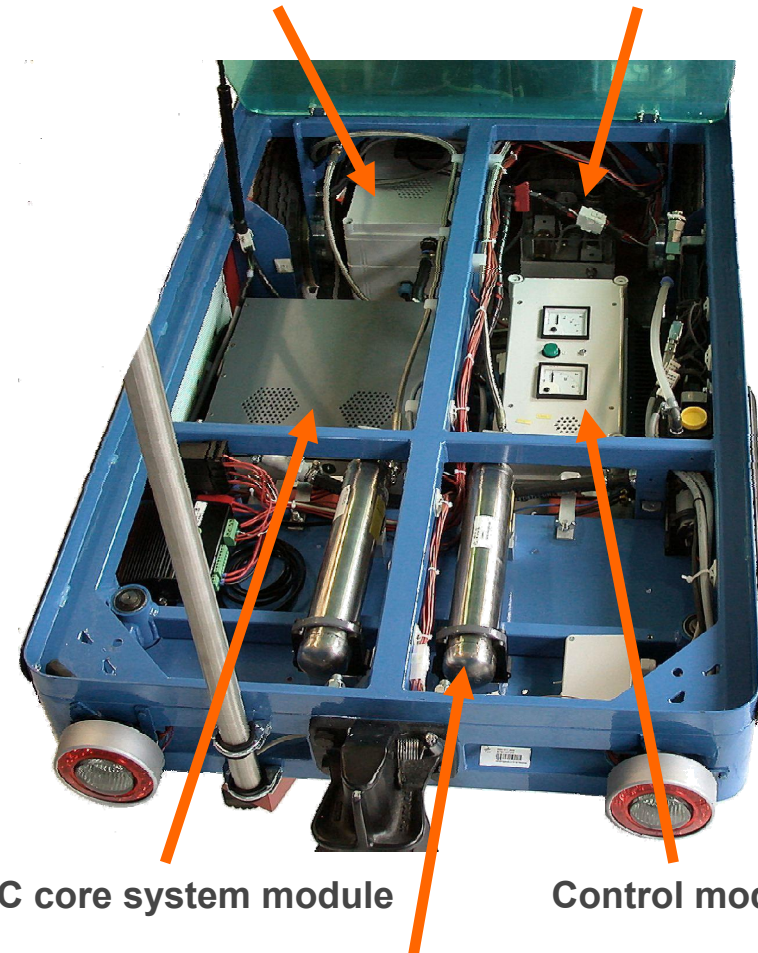


# Airport Apron Vehicle VFF with PEFC-Hybrid Drive Train



Air supply module

H<sub>2</sub> supply module



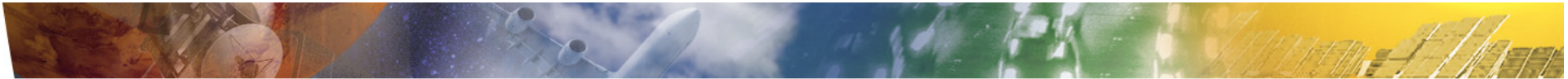
PEFC core system module

Control module

H<sub>2</sub>- storage module

## Vehicle innovations:

- Fuel cell power supply in hybrid configuration
- Power: 1,2 kW<sub>n</sub> / 3,0 kW<sub>p</sub>
- Vehicle control via joystick
- Front wheel drive with two hub motors
- Free moving rear wheels
- Energy-saving LED-lighting



# Airport Aprone Area Pulling Tractor with Fuel Cell Hybrid Power Supply

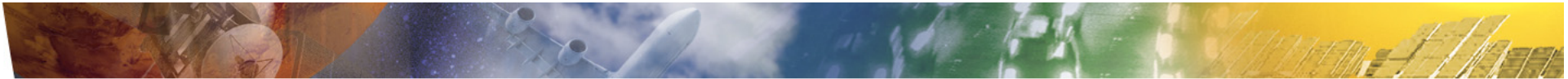
PEFC-Emergency-  
Shutdown

H<sub>2</sub>-in Air  
Measurement



Cooling System  
and  
Hydrogen Supply  
Interconnection

PEFC-System  
under the  
Driver Seat



# Luggage Pulling Tractor with Fuel Cell Hybrid Power Drive Train

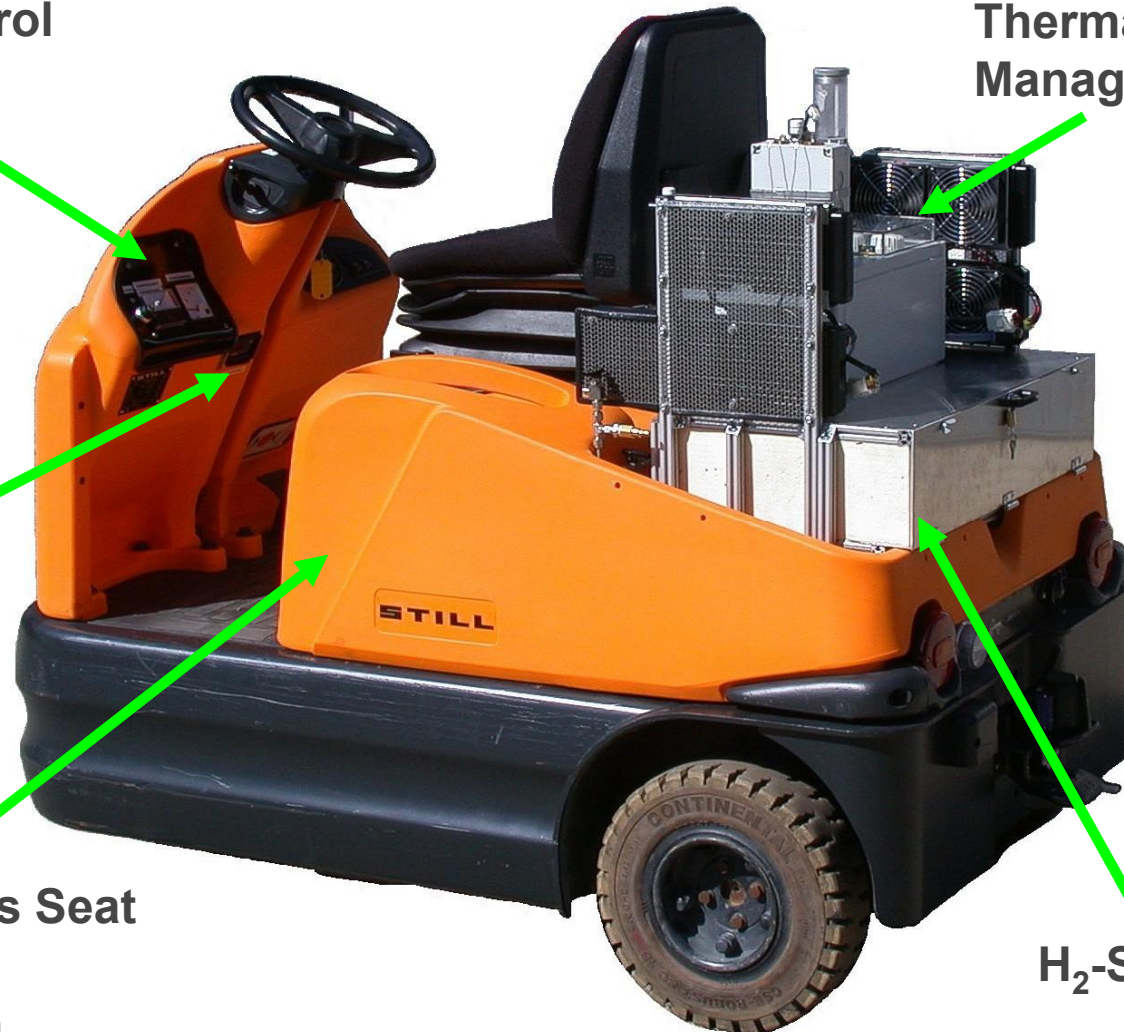
FC System Control

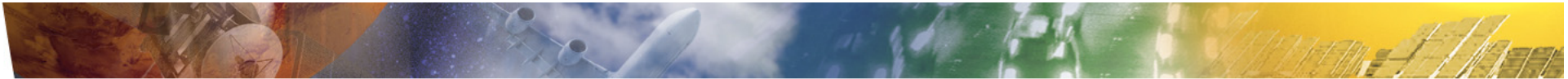
Thermal  
Management Module

H<sub>2</sub>-Safety  
System

PEFC-System  
under the Drivers Seat

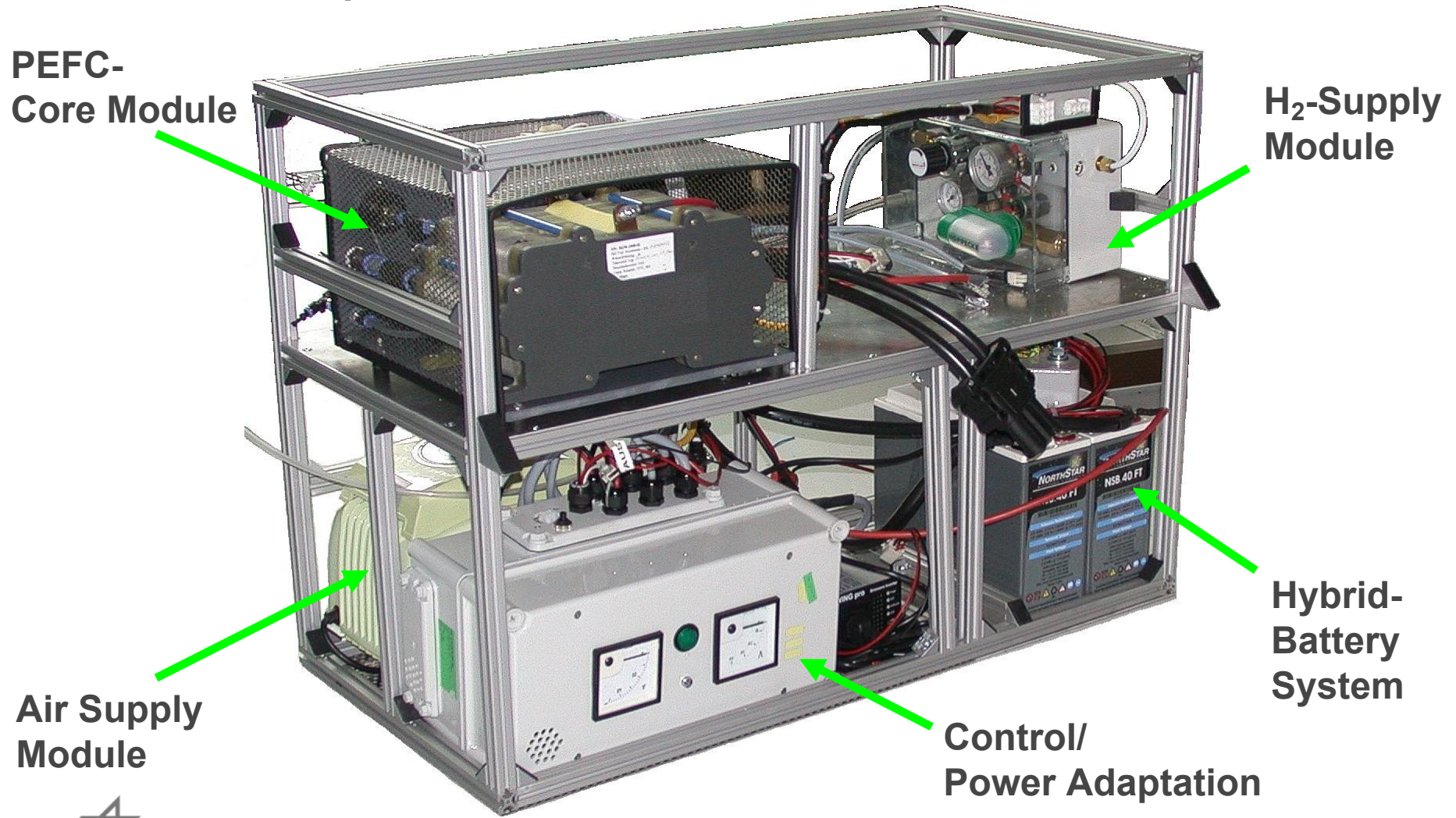
H<sub>2</sub>-Storage Module





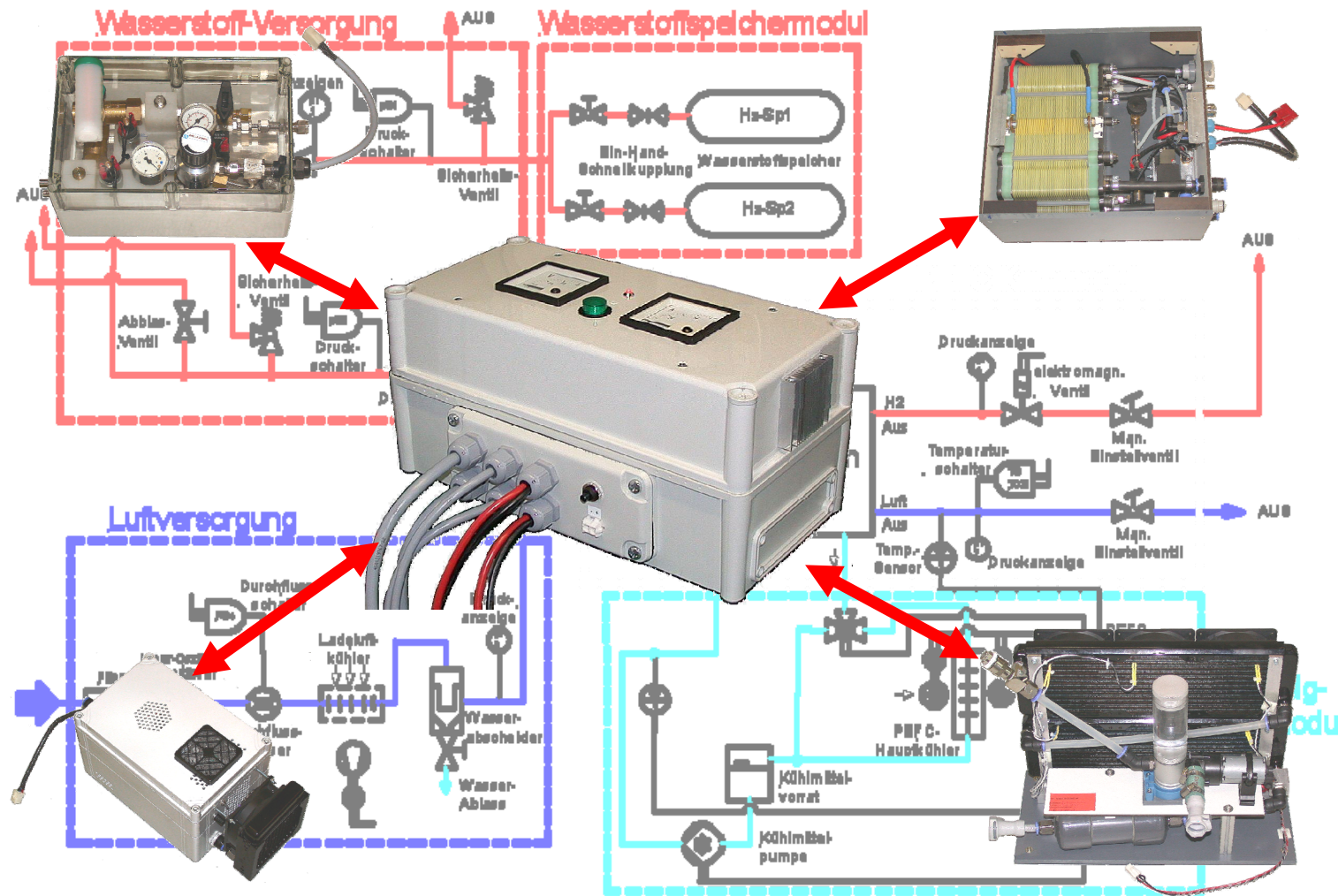
# Modular 2,1kW<sub>N</sub> PEFC-System

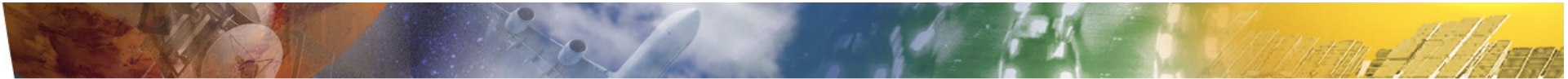
## Identical Concept between 1,2 and 2,4kW



# Centralised Subsystem Development

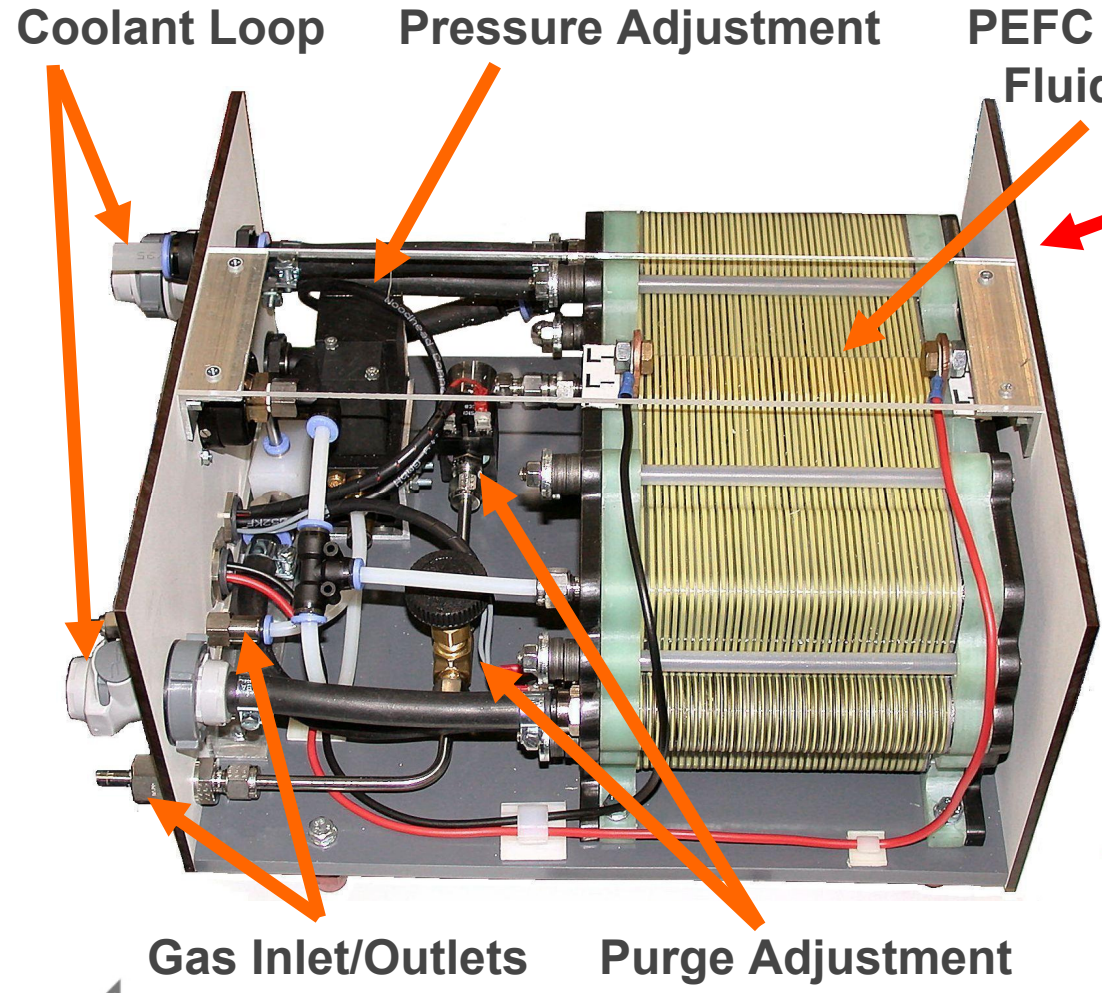
## The same Control Module for all FC Systems Variations





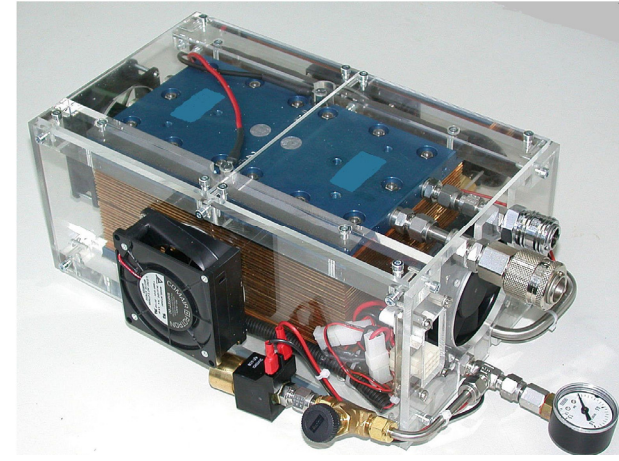
# PEFC Subsystems

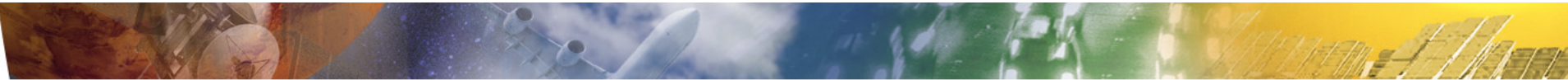
## PEFC Core Module



Liquid-Cooled Stack  
 $1,2kW_N$

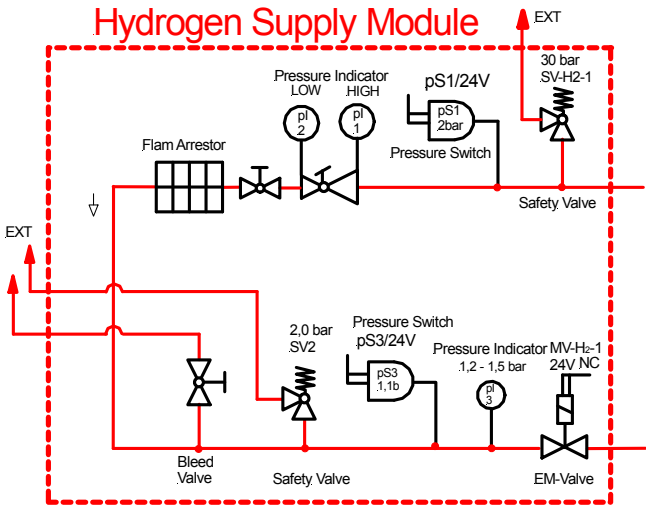
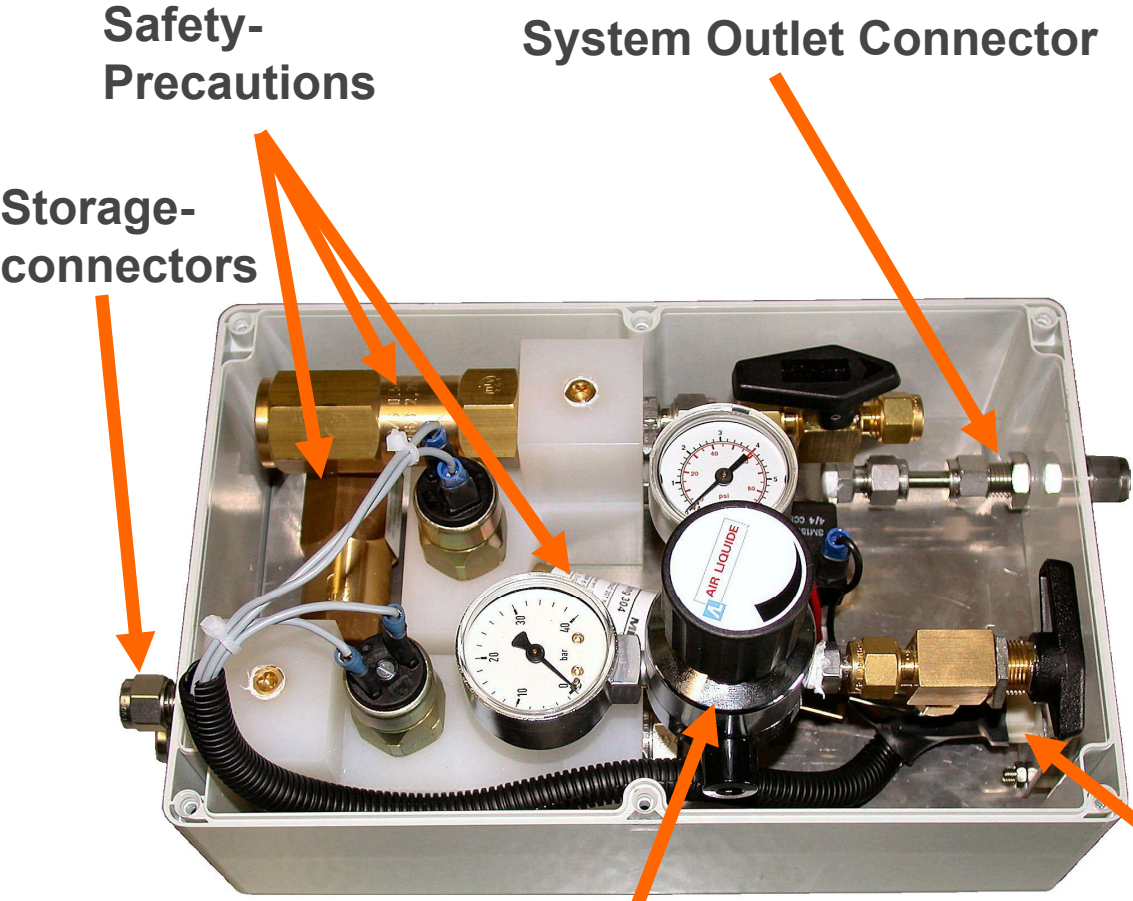
Air-Cooled Stack  $0,5kW_N$





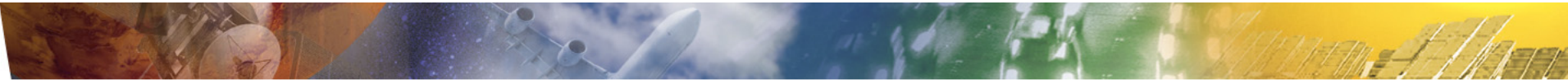
# PEFC Subsystems

## H<sub>2</sub>-Supply Module of 0,4 – 1,4kW PEFC-Systems



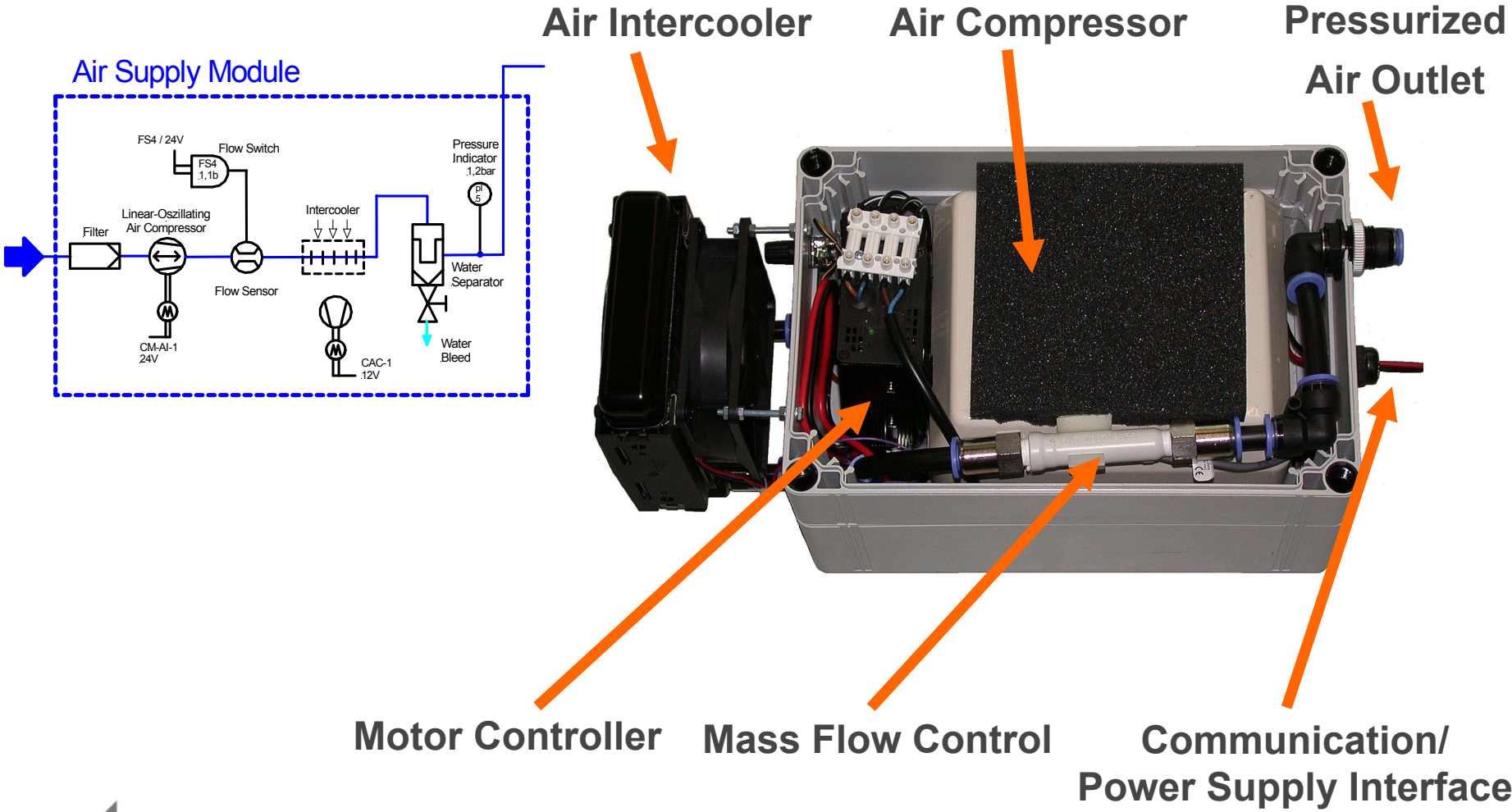
**Pressure Adjustment**

**Communication/  
Power Supply Interface**

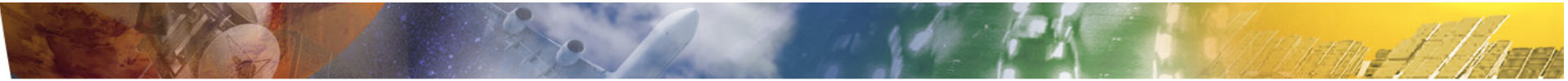


# PEFC Subsystems

## 1,2kW Air Supply Module with Sound Absorption

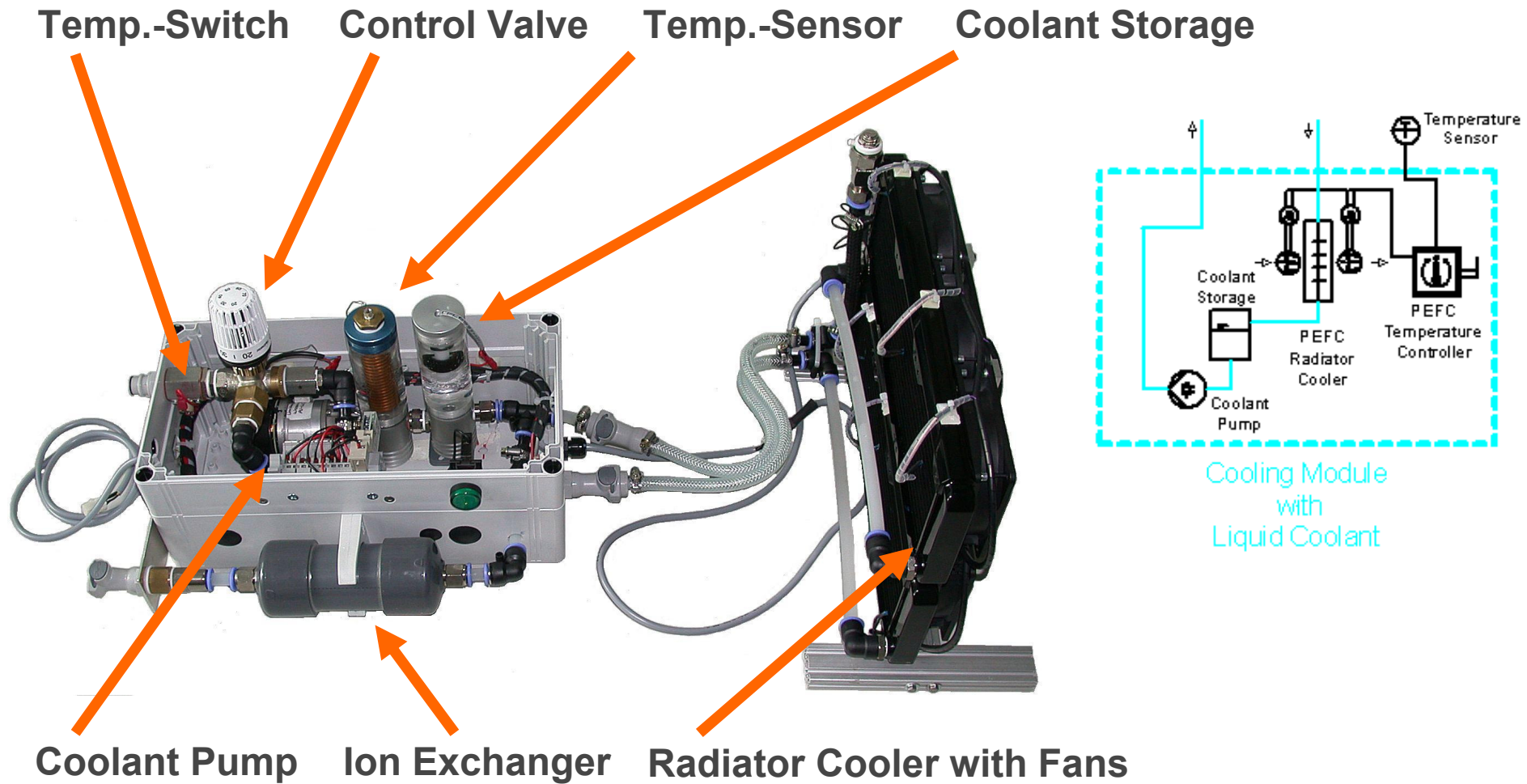




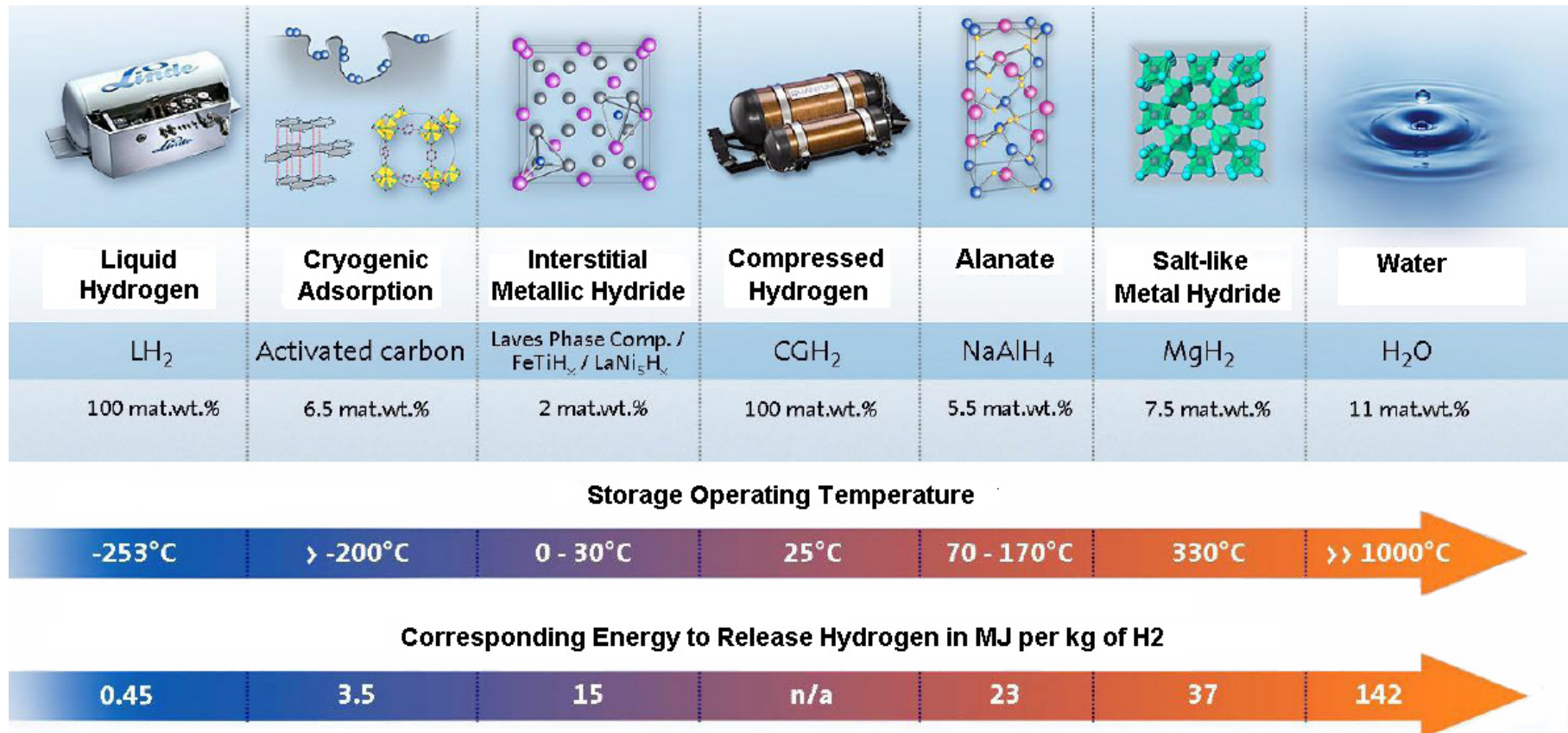


# PEFC Subsystems

## 1,2 – 2,4kW Cooling Module with Temp.-Controlled Coolant Loop

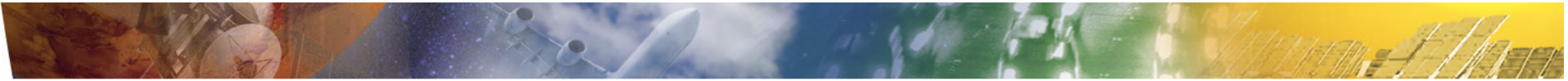


# Hydrogen Storage Technologies - their Boundary Conditions of Operation



B. Bogdanovic, U. Eberle, M. Felderhoff, and F. Schüth / Scripta Materialia 56 (2007) 813-816  
R. von Helmolt, U. Eberle / Journal of Power Sources 165 (2007) 833-843

Source: Dr. Eberle GM / Opel Fuel Cell Activities, F-cell 2007



## Summary

### Limitations of Hydrogen as a Fuel and Secondary Energy Carrier

- **Hydrogen is no primary energy source but a secondary energy carrier. It has to be produced with additional energetic effort from a primary energy source/ converter.**
- **Hydrogen is a clean energy carrier but with a look on the total ecologic balance it can not be cleaner than the primary energy source.**
- **Hydrogen can not be cheaper than the primary energy source.**
- **Hydrogen and fuel cells have always to compete with other environmentally friendly and sustainable technologies. They are no wonder and no panacea.**