International Automotive Congress 2017

epsilon - Small Electric Vehicle with Maximized Safety and Innovative Lightweight Body

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Institute for Automotive Engineering

Agenda

- Motivation
- Project Overview
- Concept Investigation
- Development
- Demonstrator Vehicle
- Summary

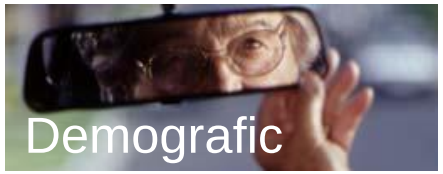
Project Overview
Motivation

- **Urbanisation** is closely connected to the evolution of mobility
- 74% of European population lives in urbanised areas
- Urban population will increase from 3.6 billion to 6.3 billion between 2011 and 2050
- New challenges in terms of **congestion** as well as **pollution** and **noise emissions**
- **Shared mobility** and services become more important

Connectivity

Individualisation of mobility needs

Accidents



change

STOCKHOLM A
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Crime

resources

Emissions

Public debt

Rising costs of energy and fuel

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Funded by the Seventh Framework Programme of the European Union

small **E**lectric **P**assenger vehicle with maximized **S**afety and **I**ntegrating a **L**ightweight **O**riented **N**ovel body architecture

Funded by
European Community's
7th Framework Programme

Project Budget
2.5 Million Euro (project total)

Project Duration
November 2013 to
February 2017

Project Overview
Consortium

- Exterior and interior prototyping

HPL Proto

- Project coordination
- Concept investigation
- Exterior & interior design
- Package
- Body design (CAE, CAD)
- Drivetrain layout
- HMI

fka

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- Active crash structures and restraints

Autoliv

Axon

- Body structure prototyping
- Full vehicle integration and assembly

Fraunhofer LBF

- CFRP rear axle

virtual vehicle

- Drivetrain layout
- Energy efficiency
- HVAC

TU Graz

- Integral safety
- Battery integration
- Crash testing

CRF CENTRO RICERCHE FIAT

- Business case study
- Chassis design & build
- Vehicle dynamics tests

Agenda

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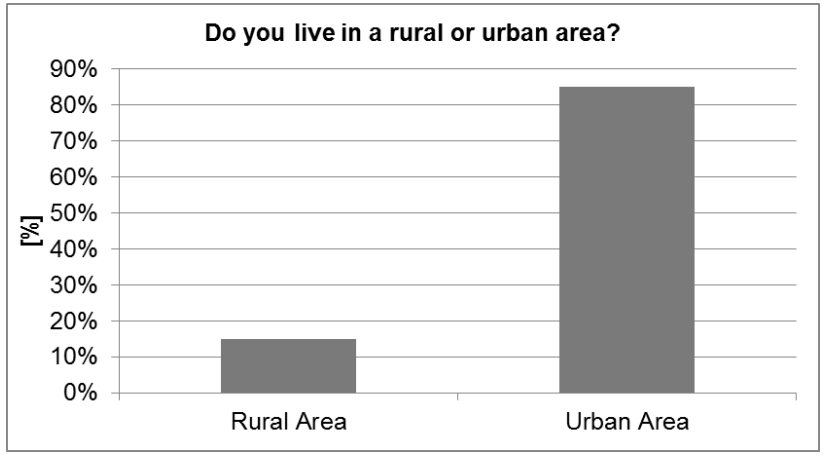
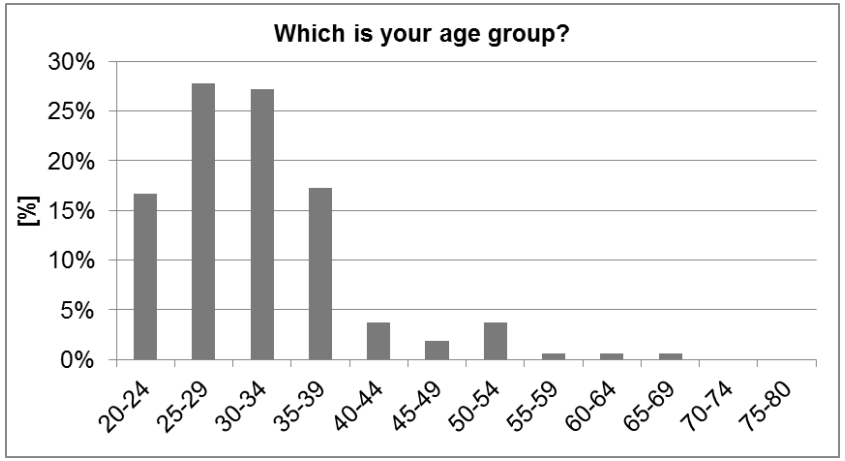
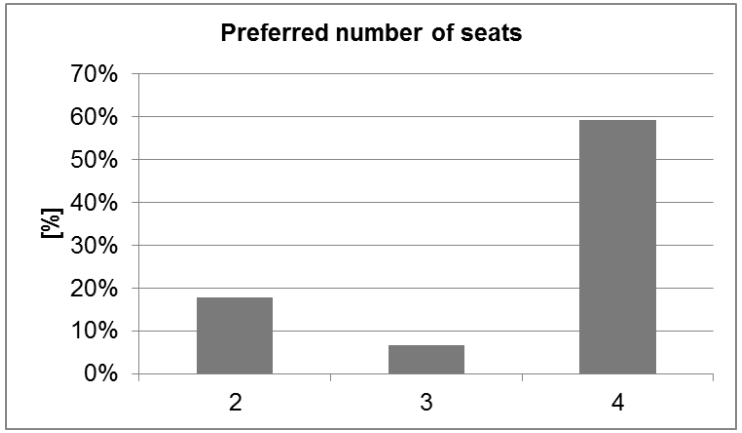
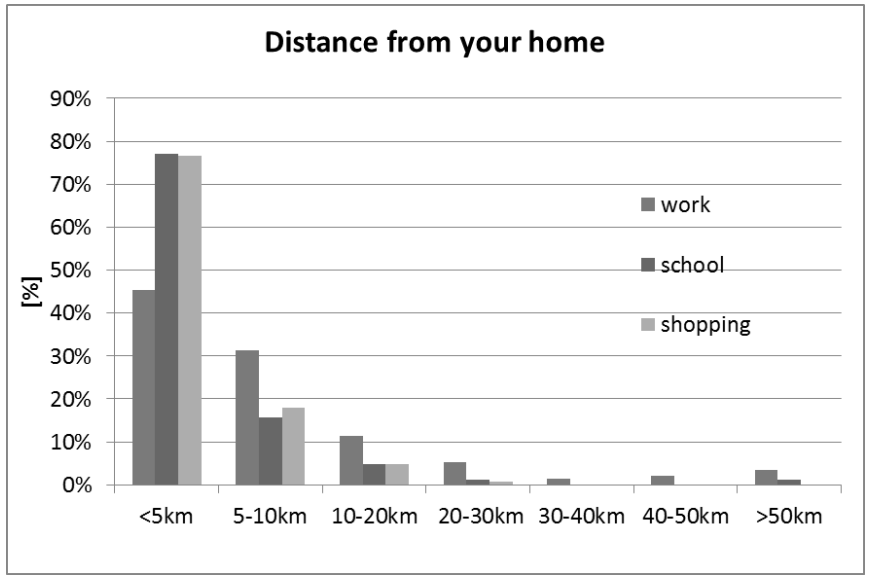
Concept Investigation
Scenario and market analysis – urban mobility

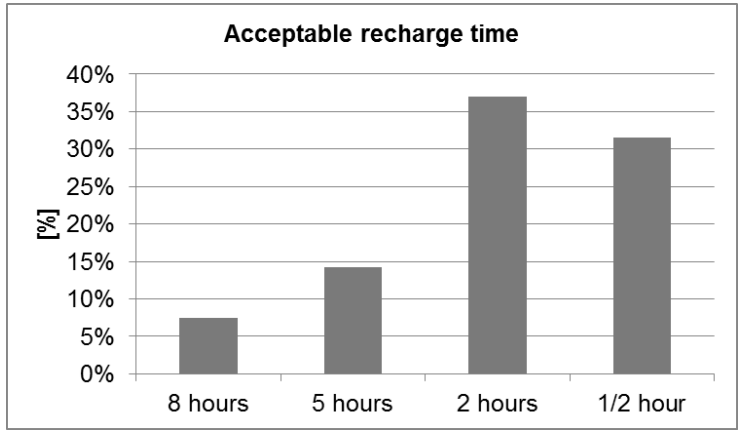
n = 162

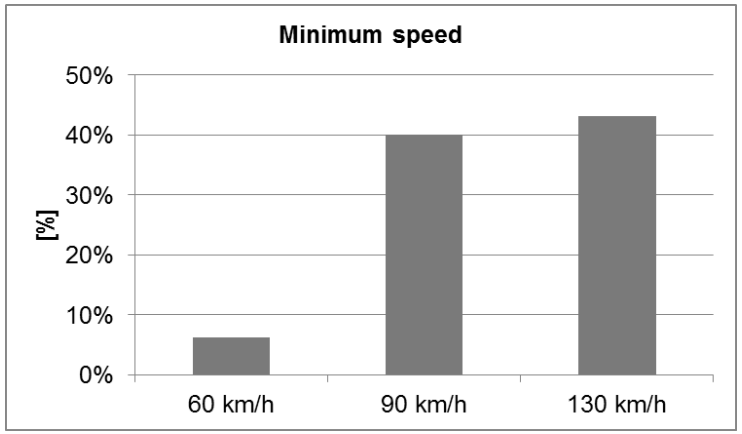




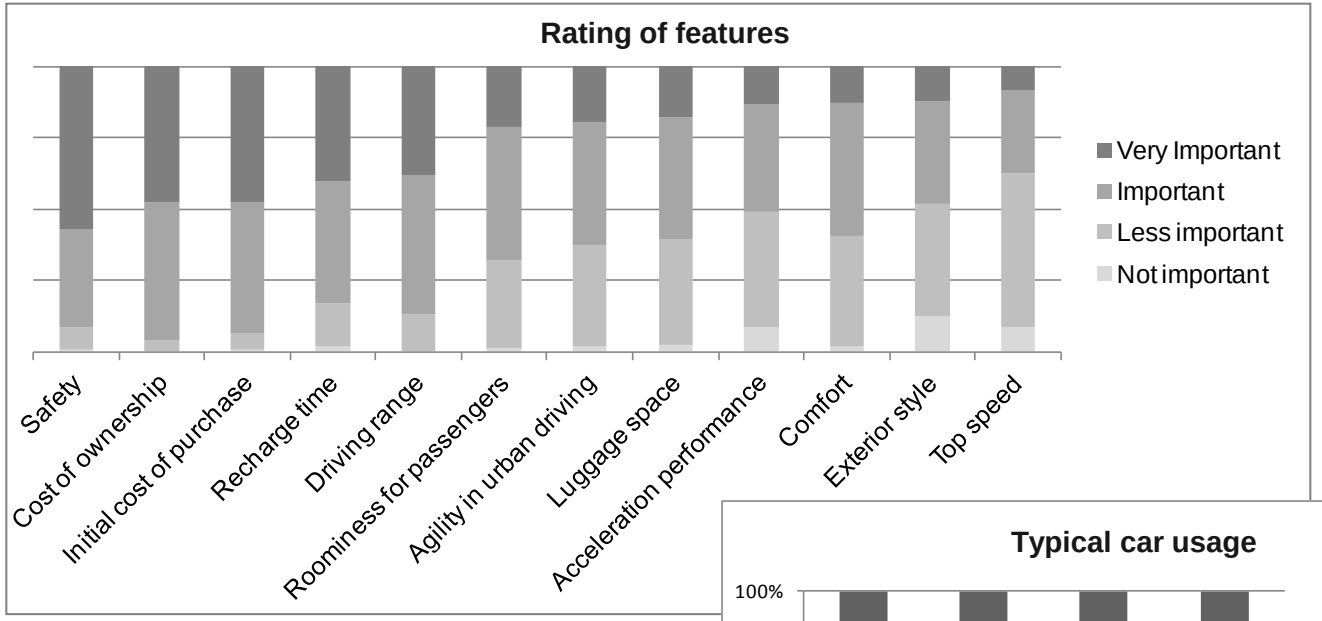








Concept Investigation
Scenario and market analysis – urban mobility



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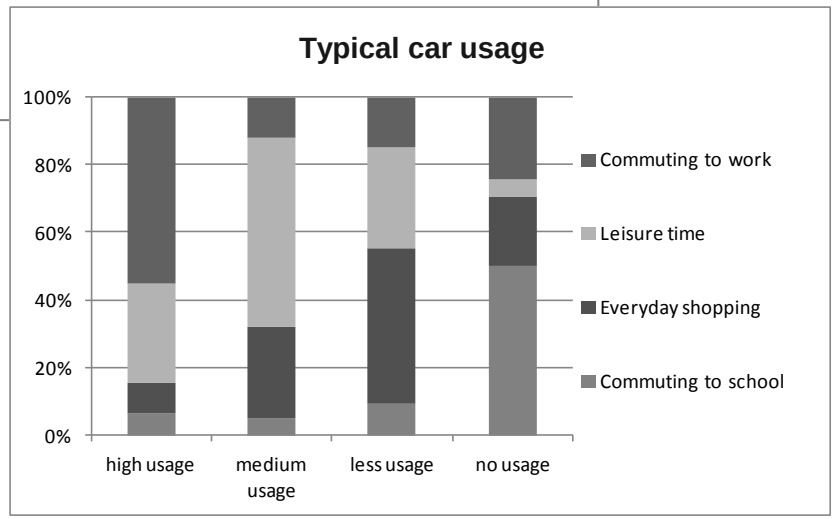


- **Commuting** is the main use case for urban individual transport, followed by leisure time activities.
- **Safety** is one of the most important features.
- Low purchase **costs and TCO** are required.
- **Ease of use** (range, recharge time) **and agility** in urban driving with a possible top speed of at least 110 km/h should be realised.
- Despite road space becoming more and more congested, **sufficient space and comfort** remain key attributes.

Minimalistic vehicle concept providing safe & efficient mobility at affordable costs

Concept Investigation
Objectives

Renault Twizy
L: 2335 mm
W: 1228 mm
H: 1454 mm

L7e
Efficiency

M1
Safety, comfort

Smart Fortwo E
L: 2695 mm
W: 1559 mm
H: 1565 mm

- Designing and prototyping the urban small electric vehicle of 2020 - 2025
- Appealing driving performance at affordable costs
- Holistic development and integration of innovative technologies
- Lighter, more energy-efficient and compact than today's sub-compact cars
- Higher safety, transport capacity and comfort than powered two-wheelers
- Closing the gap between ultra light vehicles (L7e) and conventional cars (M1)

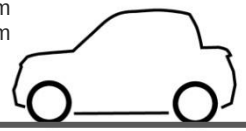
Concept Investigation
Package

Concept Specification Sheet

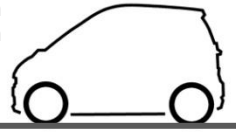
References

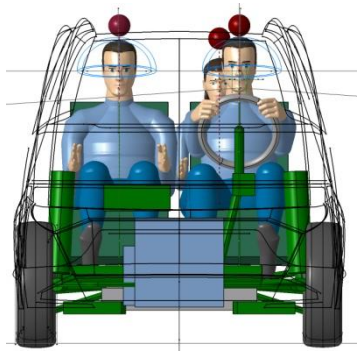
Renault Twizy
L: 2335 mm
W: 1228 mm
H: 1454 mm

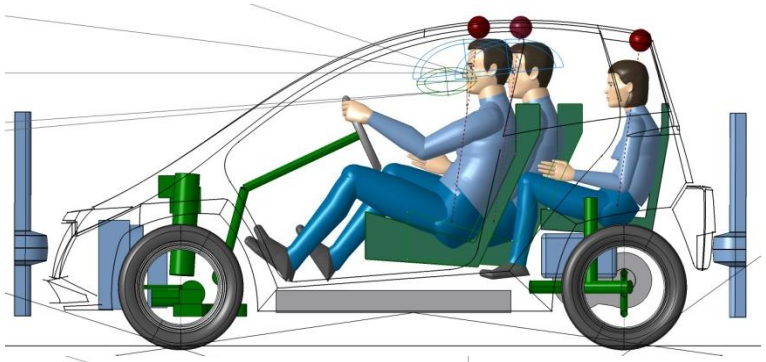
Tazzari Zero
L: 2880 mm
W: 1560 mm
H: 1425 mm

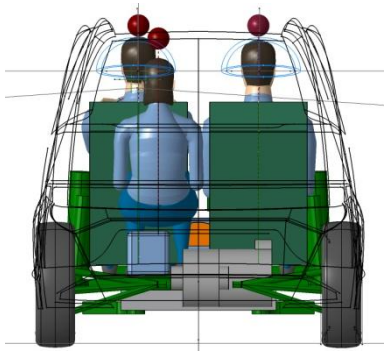


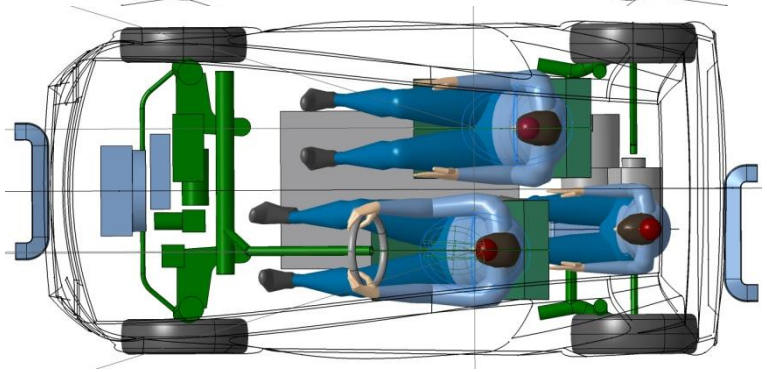
Smart Fortwo E
L: 2695 mm
W: 1559 mm
H: 1565 mm











Vehicle Type

Segment	M0, Sub-A
Seats	2 (M95th) + 1 (F5th)
Units per year	50,000
SOP	2020 - 2025

Technical Specs and Targets

Curb weight	600 kg
Gross vehicle weight	850 kg
Range (urban)	> 150 km
Acceleration (1-100 km/h)	< 10 s
NCAP rating	4 stars

Functional Objectives

- Suitability for car sharing
- Mainly for urban commuting
- Modularity for families
- Easy to use
- Agile in urban environment

Exterior Dimensions

Length	3100 mm
Width	1500 mm
Height	1460 mm
Wheelbase	2040 mm
Front track	1295 mm
Rear track	1257 mm

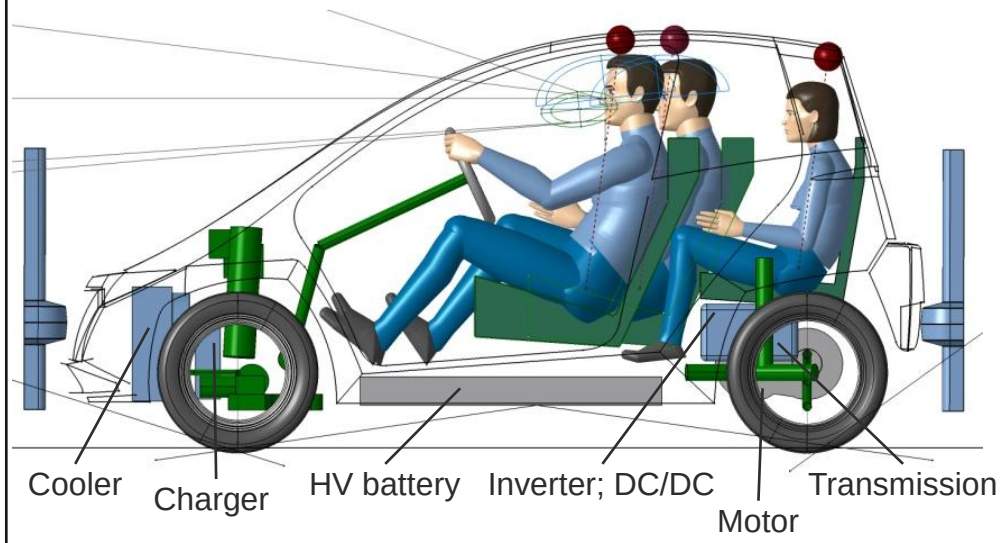
Interior Dimensions

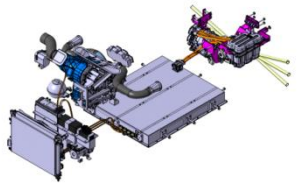
Headroom driver	980 mm
Headroom co-driver	980 mm
Headroom 2nd row	850 mm
Shoulder room front	1190 mm
Shoulder room rear	1080 mm
Trunk volume	100 – 260 l

Concept Investigation
Package

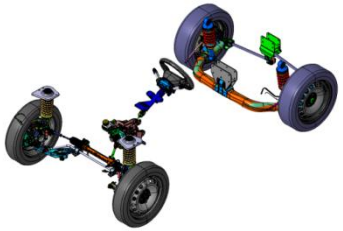
Final Package

Package concept → Drivetrain development → Vehicle concept

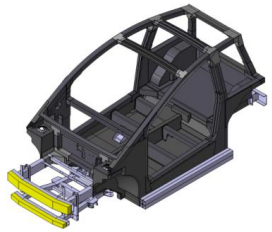


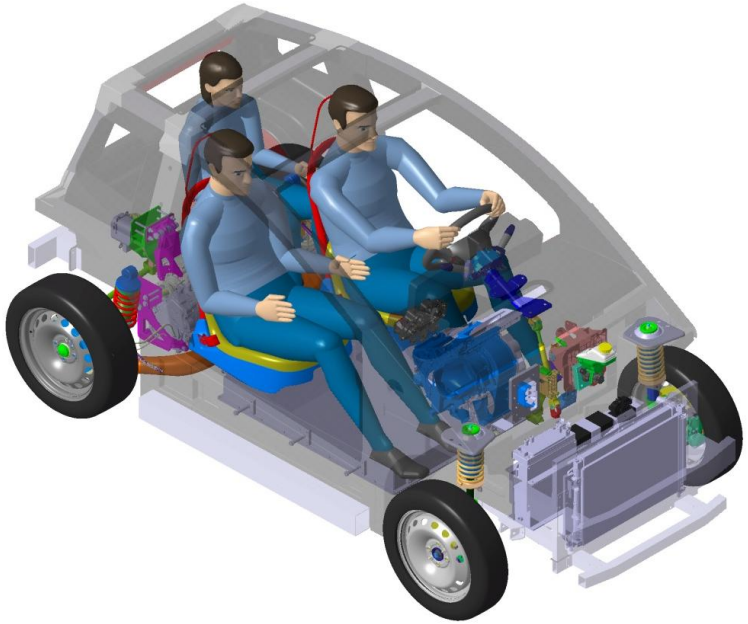


Chassis development



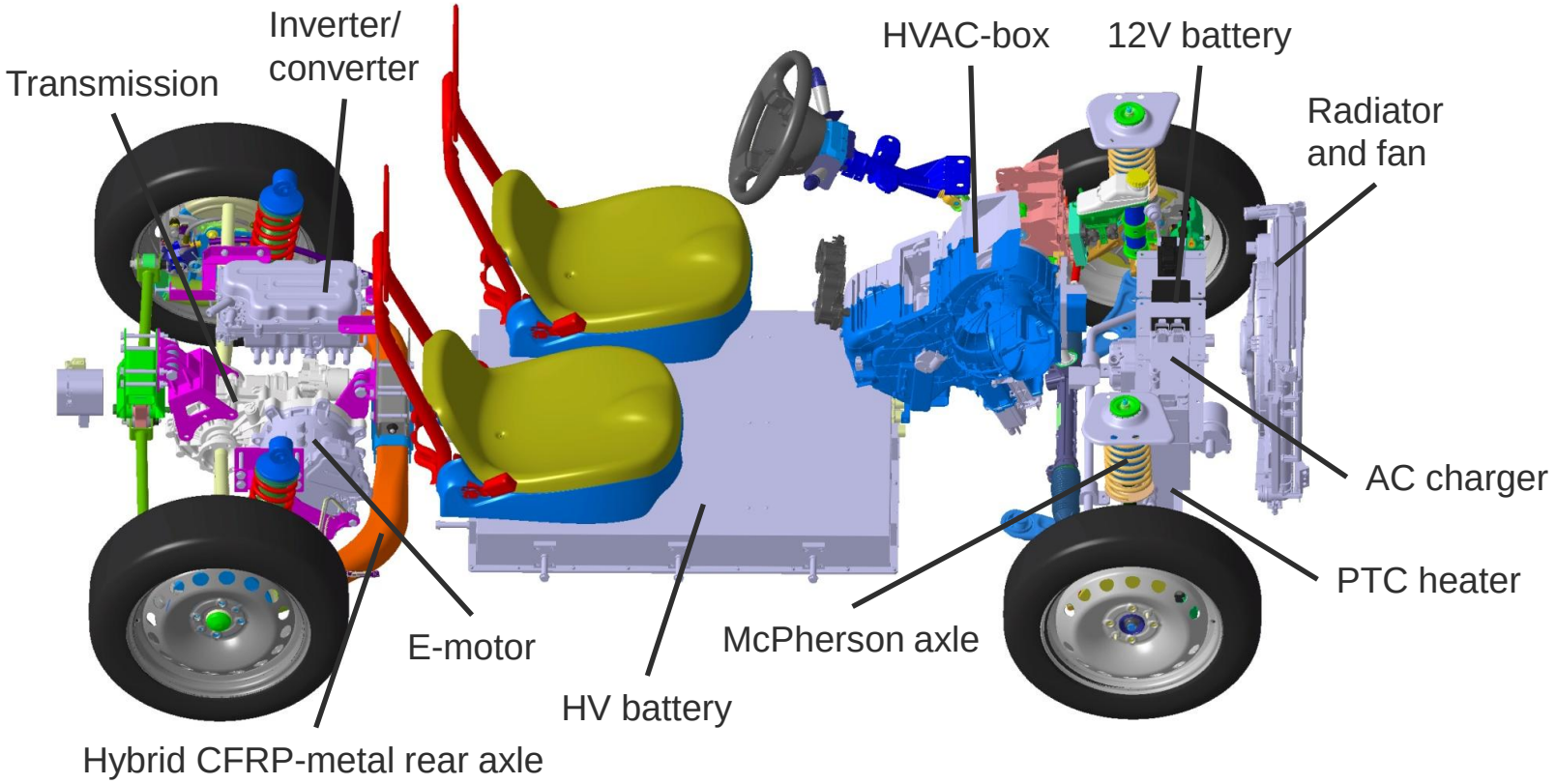
BiW development

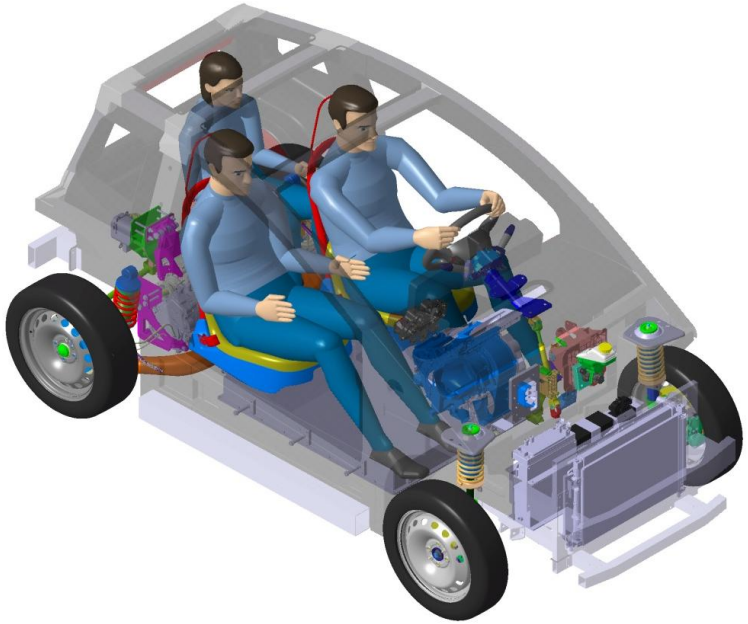




Concept Investigation
Package

Final Package





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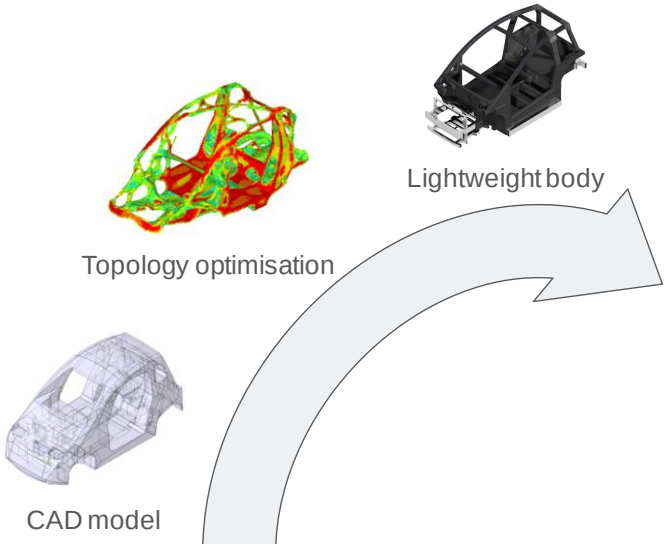
Development
Structural BIW concept

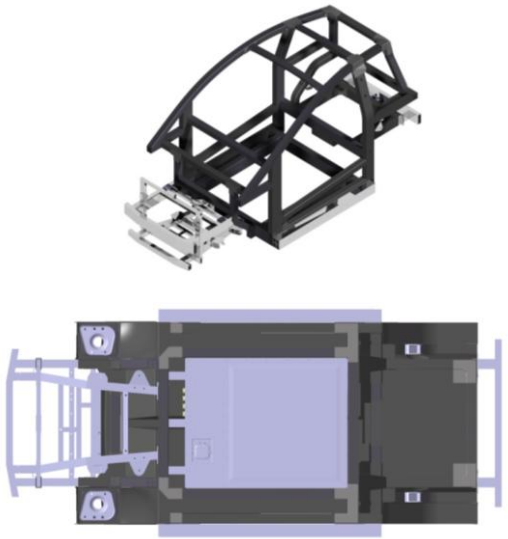
Holistic lightweight design approach

Geometrical lightweight design



- Lightweight design by topology optimisation

Conceptual lightweight design



- Structurally integrated battery
- Structurally integrated rear seat

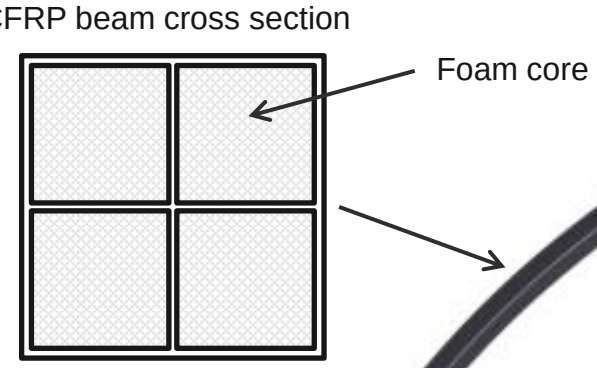
Material lightweight design

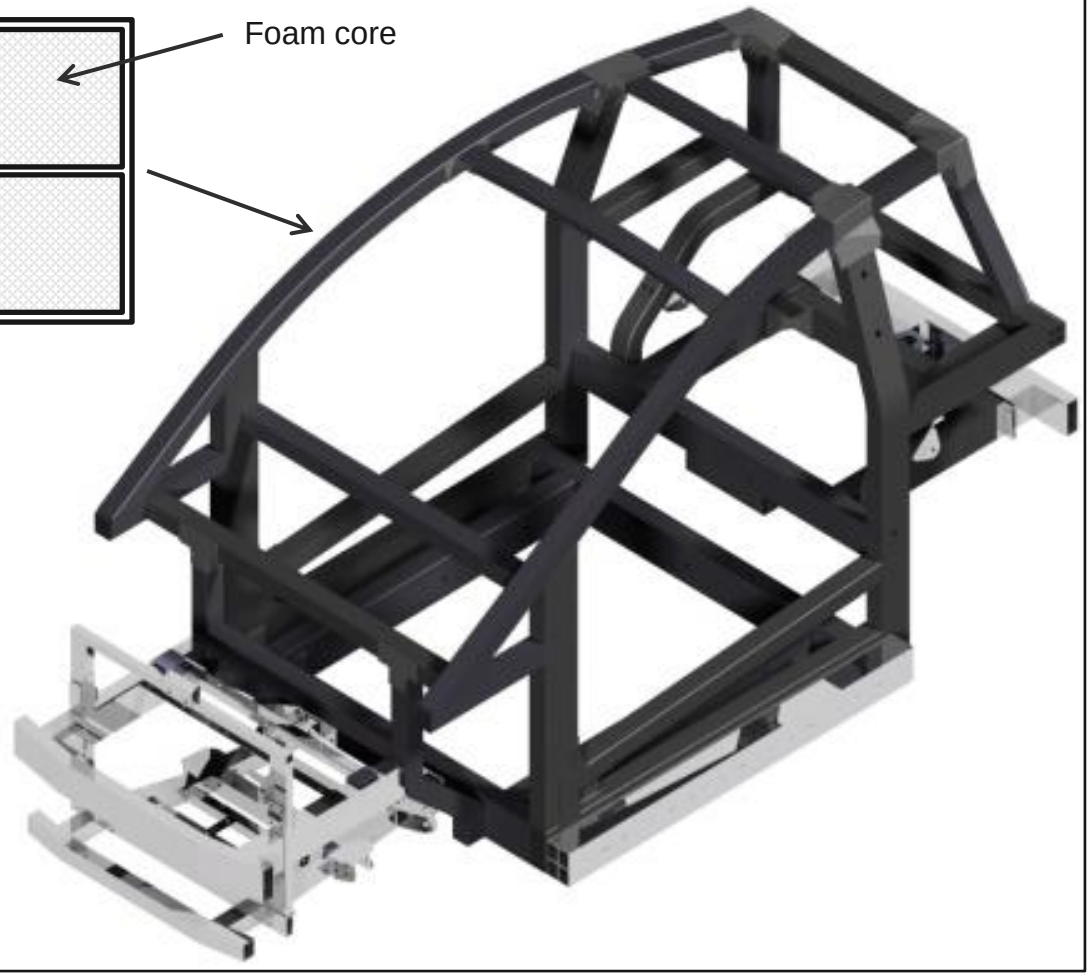
- CFRP-Al-Space-Frame
  - Aluminium
  - CFRP

Development
Structural BIW concept

Body in White

- CFRP-Al-Space-Frame architecture
- CRFP space frame enclosing the passenger compartment
  - Axontex technology by partner Axon
  - LDPE foam cores overbraided with HT carbon fibre
  - Additional braiding process leads to multi-chamber cross section
  - Filling with PU resin by VARTM in a tool
  - Curing in autoclave
- Aluminium extrusion profiles for front, rear and side deformation zones





Development
Structural BIW concept

Body in White

CFRP-Al-Space-Frame

Tailored shear panels

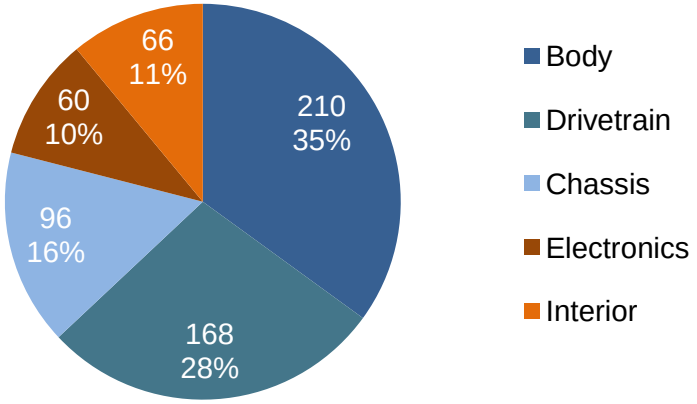
Structural nodes

Plastic exterior panels

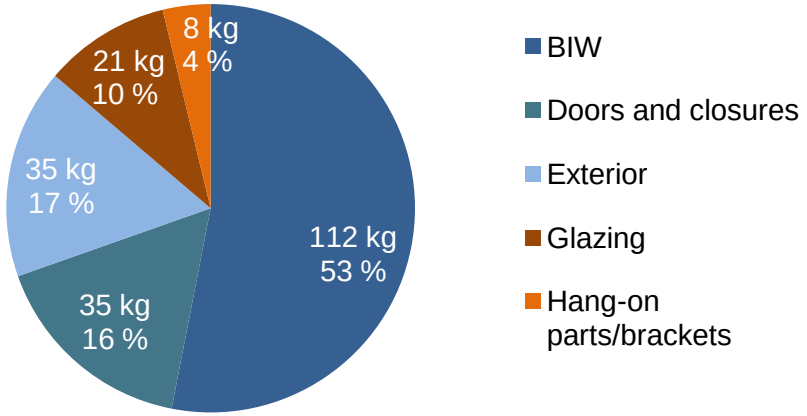
- A multi material solution, based on CFRP and aluminium
- Non-structural injection moulded outer panels (GFRP for prototype)

Development
Structural BIW concept

Weight target full vehicle: 600 kg

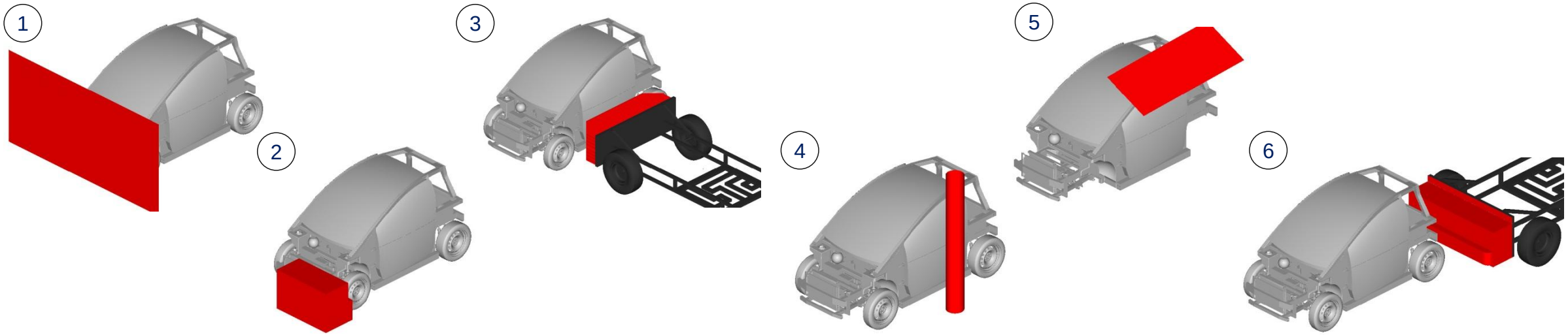


Weight target body: 210 kg
Final weight: 211 kg



Development
Structural BIW concept

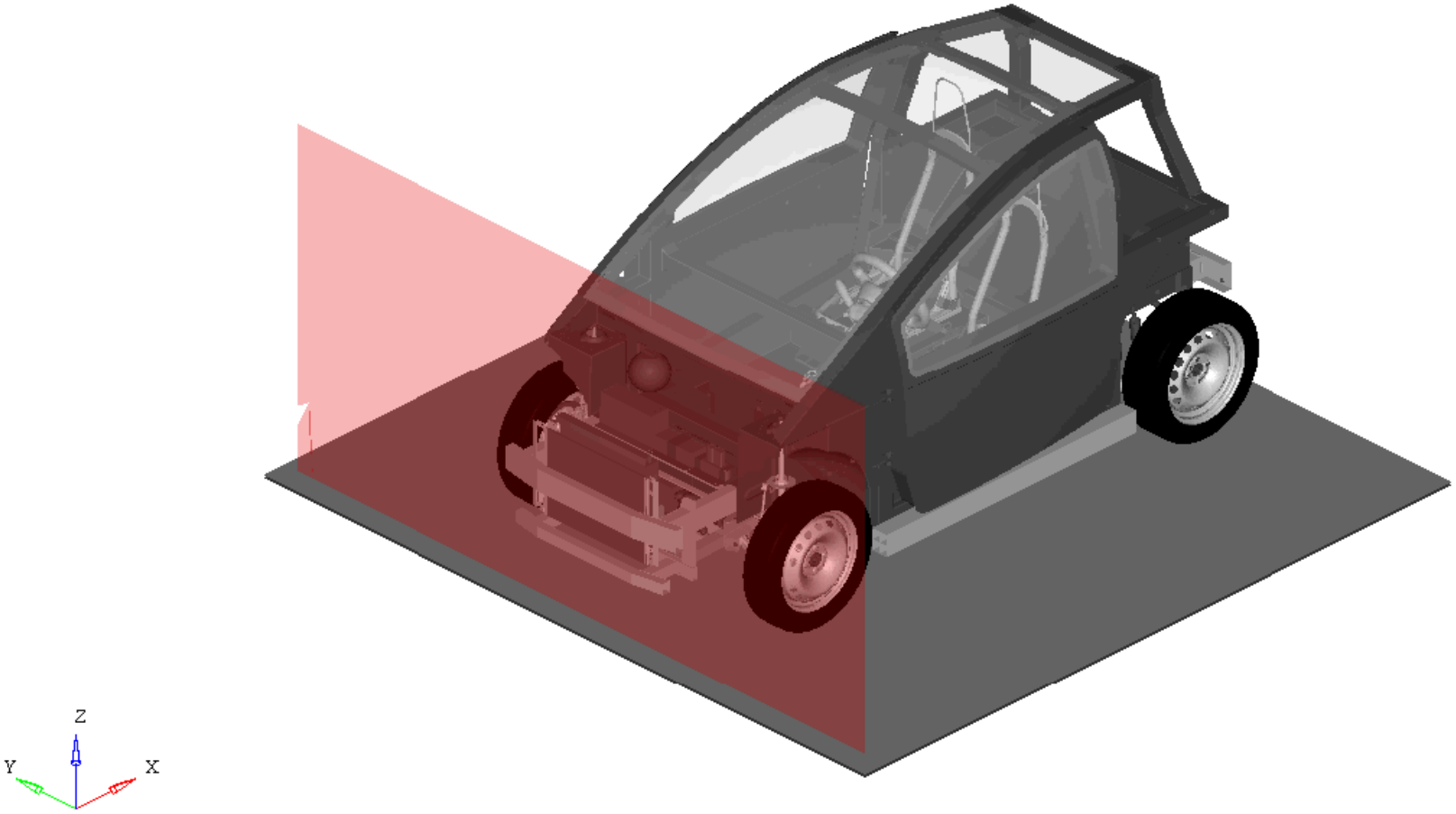
Crash load cases



#	Crash Test	
1	Euro NCAP full width rigid barrier front crash	✓
2	Euro NCAP offset deformable barrier front crash	✓
3	Euro NCAP moveable deformable barrier side crash	✓
4	Euro NCAP side pole crash	✓
5	FMVSS 216 roof test	✓
6	FMVSS 301 offset deformable barrier rear crash	✓

Development
Structural BIW concept

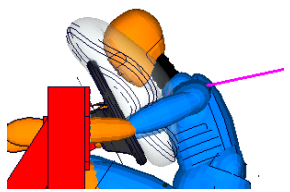
Euro NCAP full width rigid barrier front crash



video

Development
Passive safety – restraint system layout

- **Driver** restraint system
  - Dummy 50th , ODB 65 km/h

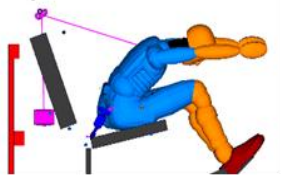


Head gap = 40 mm
HIC_{36ms}= 565
Cd = 42 mm

  - Dummy 5th , FW 50 km/h (Adaptive load limiter)

Head gap = 35 mm
HIC_{36ms}= 350
Cd = 45 mm

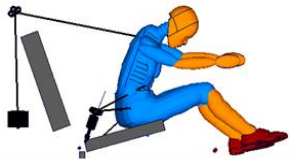
- **Passenger** restraint system
  - Dummy 50th , ODB 65 km/h



HIC_{36ms}= 235
a_{3ms} = 37 g
Cd = 37 mm

Neck F_z = 1.58 kN
Neck F_x = 0.75 kN
Neck M_y = 13.0 Nm

  - Dummy 5th , FW 50 km/h (Adaptive load limiter)



HIC_{36ms}= 64
a_{3ms} = 29 g
Cd = 37 mm

Neck F_z = 1.06 kN
Neck F_x = 0.50 kN
Neck M_y = 13.0 Nm

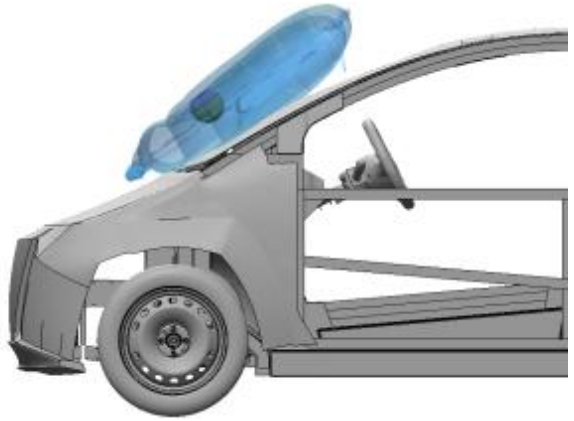
[TUG]

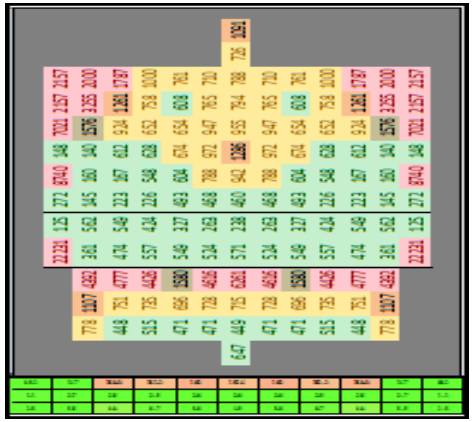
Development
Pedestrian protection

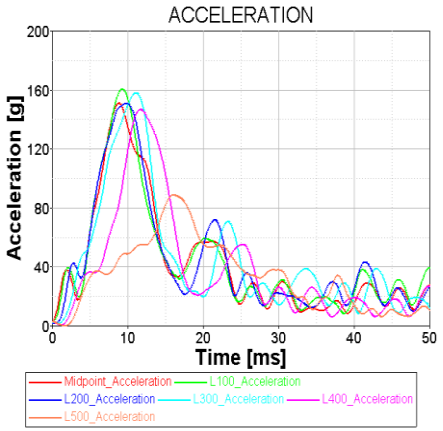
- epsilon vehicle
  - 600 kg
  - Rating: 76%

- Reference vehicles
  - 845 - 940 kg
  - Rating: 46 - 73 %

epsilon







Overall Pedestrian Results
76.0%

[TUG]


VSI
Vehicle Safety Institute
Epsilon_FW • -50,00 ms

Development
Structural BIW concept

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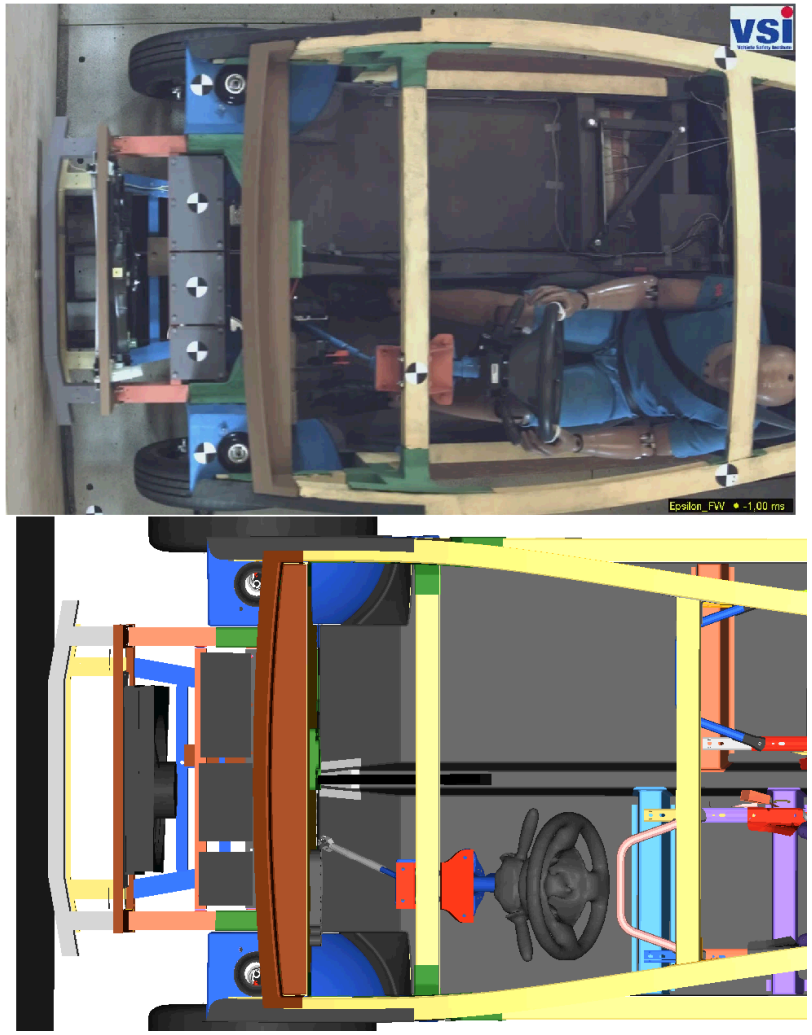
RWTH AACHEN UNIVERSITY

Euro NCAP full width rigid barrier front crash



video

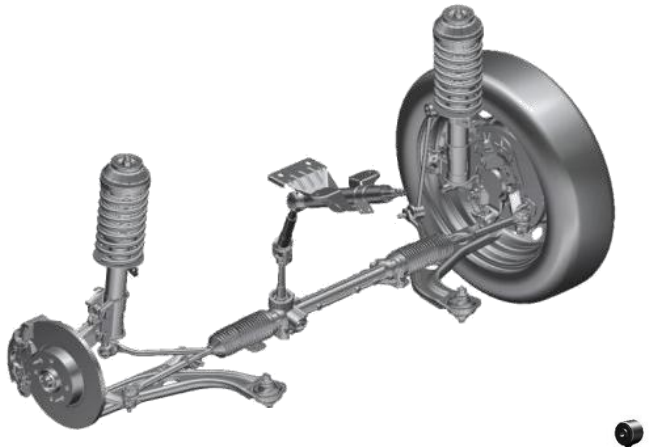
Development
Chassis

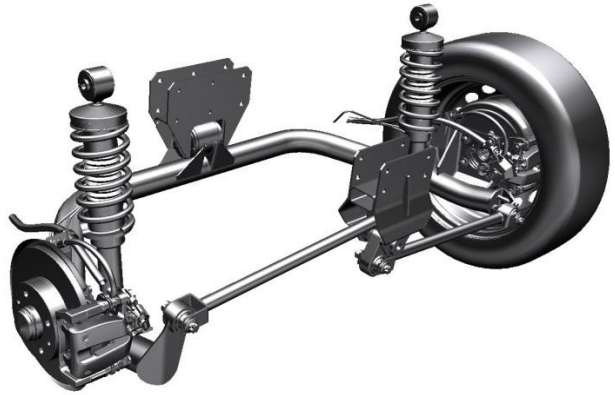
Front and rear axle

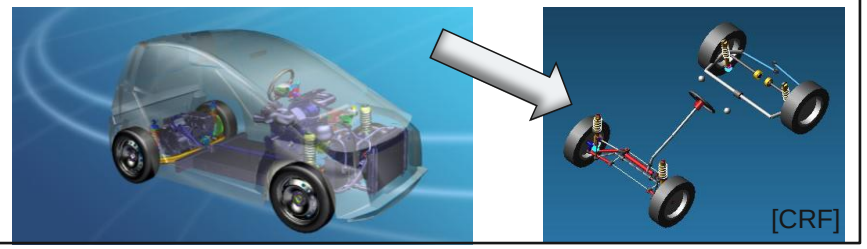
- **McPherson** front suspension and steering system derived from a donor vehicle with minor adaptations.

- An **Omega beam rear axle** has been specifically designed for the epsilon vehicle with the aim of:
  - assuring a good K&C performance
  - weight reduction (37%) with hybrid metal/CFRP solution

1: Middle section (CFRP)
2: Connection with central joint (metal)
3: Connection between middle and side section
4: Side section (metal)
5: Wheel trunk (metal)
6: Connection with the Watt-linkage (metal)



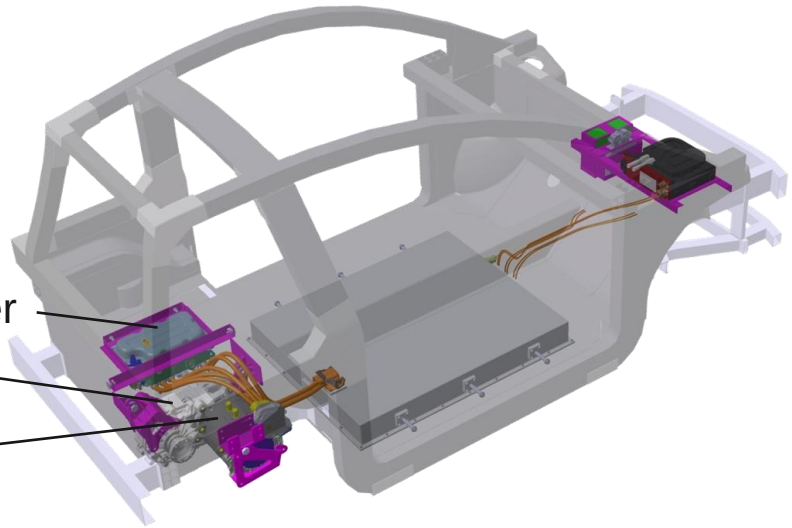




Development
Drivetrain

Drivetrain architecture

- At least 150 km driving range
- Less than 80 Wh/km
- Acceleration to 0-100 km/h in < 10 s

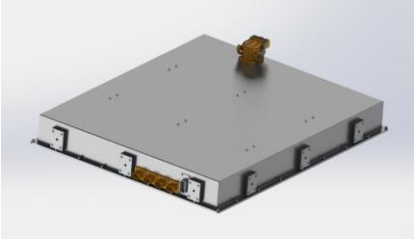


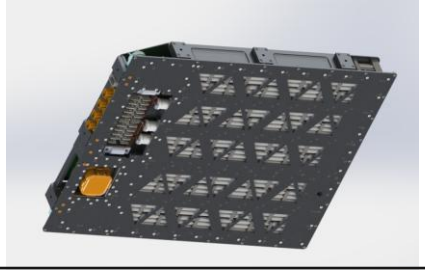
AC-charger
PTC heater
Refrigerant compressor
LV battery
Cooling system
HVAC

High voltage battery

- Integrated power distribution unit
- 110 kg (25% less than liquid-cooled version)
- Three additional electric connectors for fast charging, PTC heater, refrigerant compressor
- Cell arrangement: 102 serial 15 parallel

- Cell type: Panasonic 18650PF
- Voltage (nom.): 367 V
- Energy content: 15.6 kWh (DoD of 75%)
- Discharge current (cont./max.): 150 A /225 A (15s)



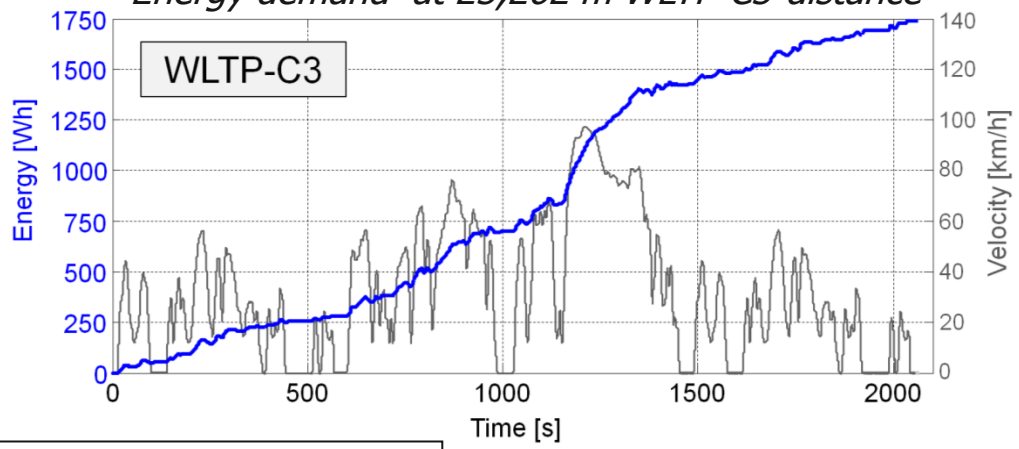


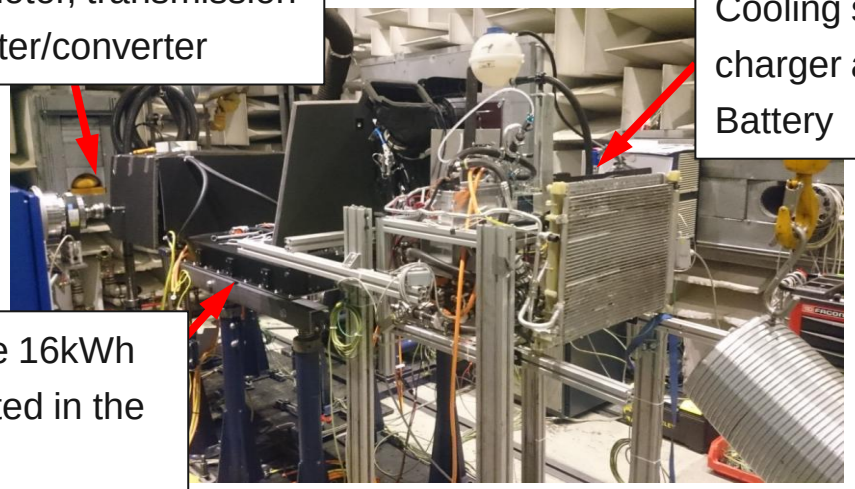
Development
Driving dynamics - drivetrain

Complete drivetrain and HVAC-system on the test rig

- HIL-Testing of complete drivetrain including ECU and HVAC system at test facilities of VIRTUAL VEHICLE
- Coupling real-world drivetrain and cooling system with virtual car, including vehicle body, chassis, driver and road
- Via this HIL-method the driving efficiency and performance is determined showing an achievement of the key criteria:
  - **156 km** driving range @ 90 % SOC to 15 % SOC
  - **76 Wh/km** energy demand
  - **8.9 s** to 100 km/h
- Regenerative braking including adjustable "Pedal-off" braking (drive pedal), regenerative braking torque is further increased if brake pedal is actuated

Energy demand at 23,262 m WLTP-C3-distance





[ViF]

Development
Exterior design

Design




Agenda

- Motivation
- Project Overview
- Concept Investigation
- Development
- Demonstrator Vehicle
- Summary

Demonstrator Vehicle
Prototyping

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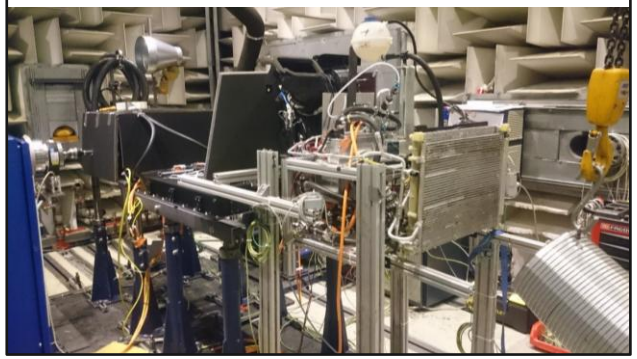
Prototyping

Body structures

Drivetrain system



Omega beam

+ Parts from donor vehicle

Full vehicle integration

epsilon

Agenda

- Motivation
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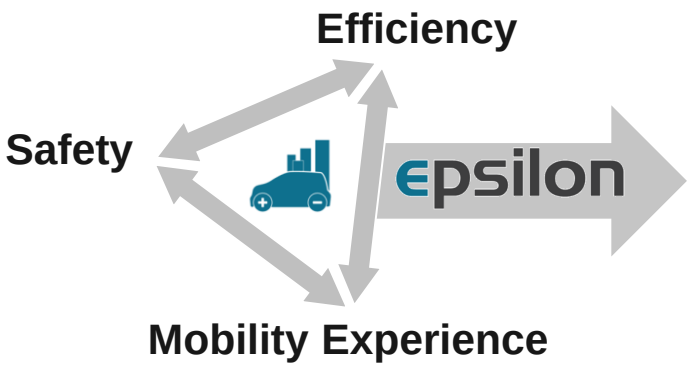
Summary

- The epsilon concept is a prototype of an **urban small electric vehicle of 2020 - 2025.**
- Specifically designed for the typical transport tasks in urban areas, based on a scenario and market analysis
- The minimalistic vehicle concept is a **safe & efficient** urban mobility concept.
- A running prototype vehicle has been built to **showcase a new vehicle class** to possible customers and stakeholders.
- **epsilon**
  - closes the **gap between L7e** vehicles **and** conventional cars (**M1**),
  - is lighter and more **energy efficient** than today's sub-compact cars,
  - offers higher **safety**, transport capacity and **comfort** compared to powered two-wheelers (PTWs) and ultra light vehicles.



Thank you for your attention!

epsilon

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On behalf of the epsilon team

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