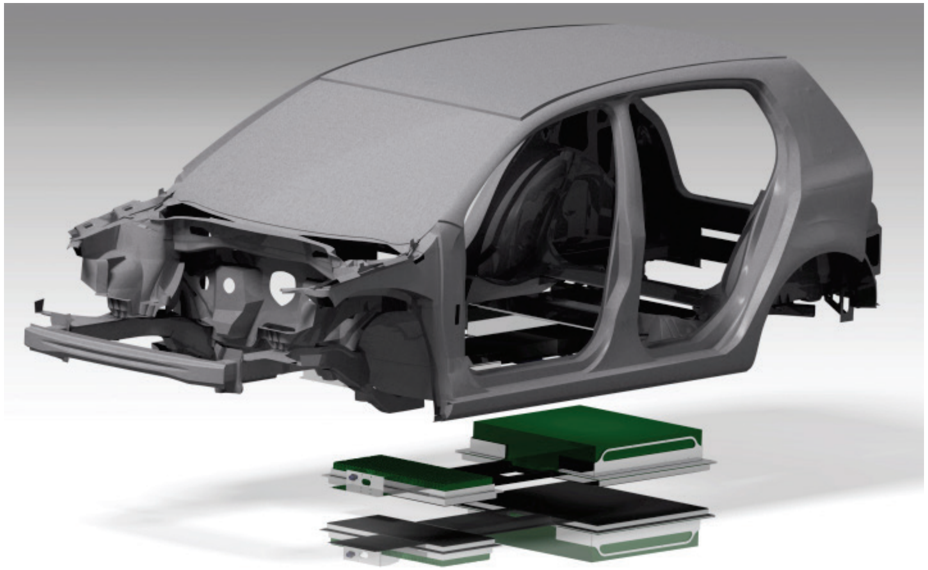

SmartBatt

Smart and Safe Integration of Batteries in Electric Vehicles

An EU funded project

SmartBatt

EU funded under 7th Framework Programme

Objectives: - Development of an electric vehicle battery focusing on
- Minimization of weight
- Optimization of safety
- Minimization of costs
- Design capable for series production

Realisation: - Battery for an A-class BEV with 100km NEDC Range
- 15% lighter than SotA (75% weight ratio between system and cell)
- Crash safety based on reference SLC Body
- Integrated BEV has same static and dynamic requirements as SLC

Budget: 3 million EUR overall budget / 2.25 million EUR funded budget

Period: January 2011 until December 2012

Consortium: 9 Partners from 5 European countries:
AIT Austrian Institute of Technology, LKR Ranshofen (AIT LKR), Axeon Technologies (part of the Johnson Matthey group), Fraunhofer Gesellschaft, Impact Design Europe, Ricardo UK, SP Sweden, Technical University Graz, Volkswagen AG

Work Package Structure

WP 1: Project Management
WP 2: Specification Analysis / Requirements
WP 3: Concept & Feasibility Study
WP 4: Risk Assessment
WP 5: Design & Development
WP 6: Hardware Build-Up & final Validation
WP 7: Assessment
WP 8: Exploitation

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1 Project Management

2 Spec. / Requirements

What are the requirements for battery integration?

- Specification analysis
- Smart integration
- Safety
- Weight reduction
- Additional functions (monitoring)
- Electric, BMS, …

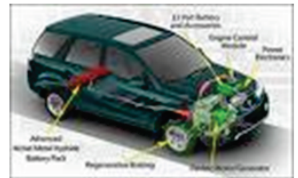
The integration has to fulfil …

Has to fulfill …, and the risk / scenarios are …

3 Concepts & feasibility study

How to fulfil the requirements and reduce the risks?

- Design concepts
- Material selection
- Functions
- Production



A smart battery integration should look like …

4 Risk Assessment

What are the risks on battery integration fulfilling the requirements?

- Electric shock
- Fire
- Gas
- Intrusions to passenger
- under which scenarios

5 Development

How is the detailed concept be working and looking?

- Detailed design
- Simulation
- Testing on small level
- Optimization

Prototype Design for Smart Battery integration

All relevant info from WPs

7 Assessment

What are the improvements / benefits?

- Identify/assess improvement of developed technology for EV market
- Quantify cost-benefit new developed technology vs. commercial solutions

6 Final validation

Does the design work?

- Prototyping
- Testing on full level

8 Exploitation

How to observe third party activities and exploit the integration?

- Papers / Conferences
- Other projects / experts
- Workshops
- Face to face meetings

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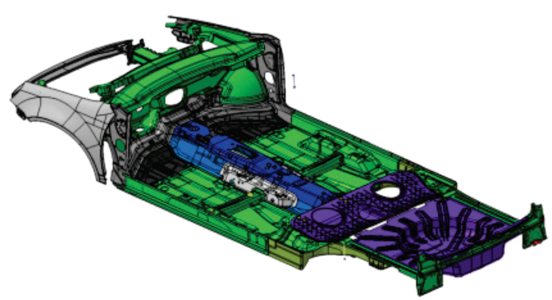
WP 2 - Specification Analysis and Requirements

- Definition / analysis of system constraints
  - platform of SLC car used
  - ~20 kWh energy content
  - 15 % lighter than comparable systems
  - Same crashworthiness as SLC

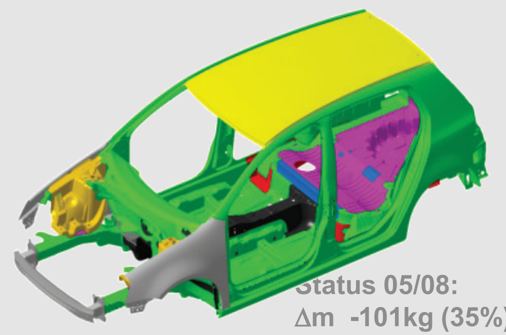
- Identification of existing standards / regulation
  - IEC/ISO
  - FMVSS
  - SAE
  - ECE R100



SuperLightCar

Materials

- Aluminium sheet
- Aluminium cast
- Aluminium extrusion
- Steel
- Hot-formed steel
- Magnesium sheet
- Magnesium diecasting
- Glasfibre thermoplastic



EUCAR
EUROPEAN COUNCIL FOR AUTOMOTIVE R&D

Weight target calculation

State of the Art

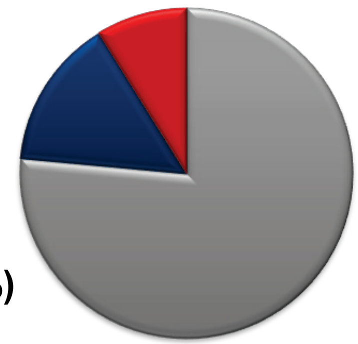
Example for a 20 kWh Battery (~200 kg):

» Cells (60 – 70 %) = 120 kg – 140 kg
» Components (10 - 15 %) = 20 kg – 30 kg
» Housing (15 - 30 %) = 30 kg – 60 kg

"Reduction of pack weight by 10 % - 15 % due to housing components."

Aimed weight target 170 – 180 kg

SmartBatt

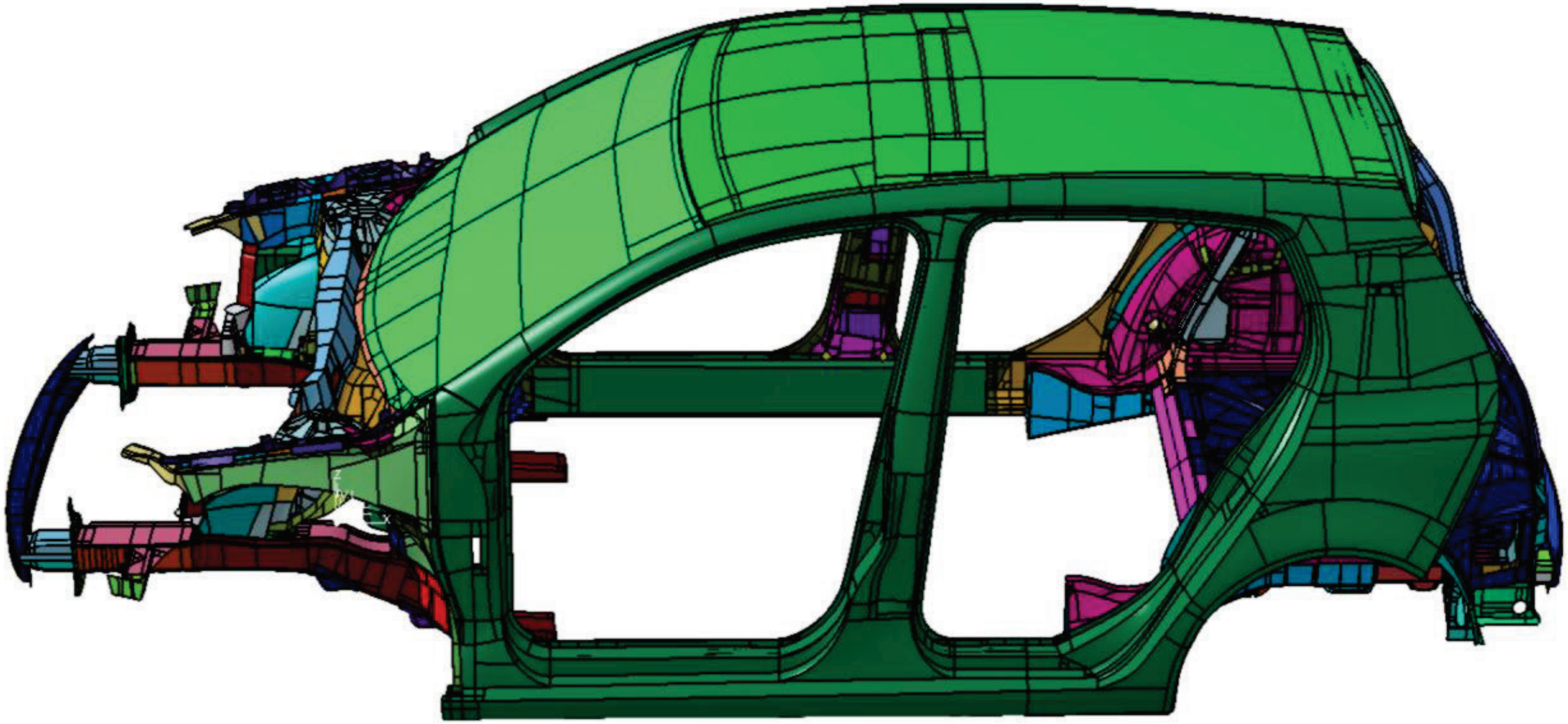


» Cells (68 – 80 %) = 120 kg – 140 kg (unchanged)
» Components (11,5 - 17 %) = 20 kg – 30 kg (almost unchanged)
» Housing (5,7 – 11,5 %) = 10 kg – 20 kg **(weight reduction of 66%)**

Function integration of "Body in white - floor" and housing to achieve this target

SLC – SmartBatt – Starting Point

SuperLightCar



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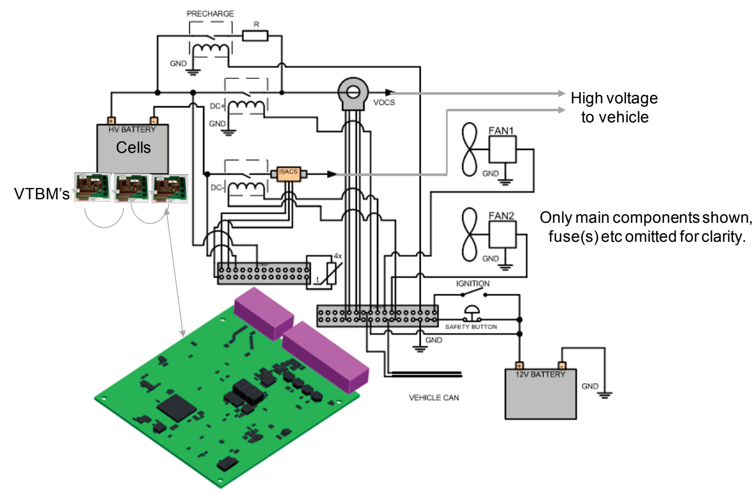
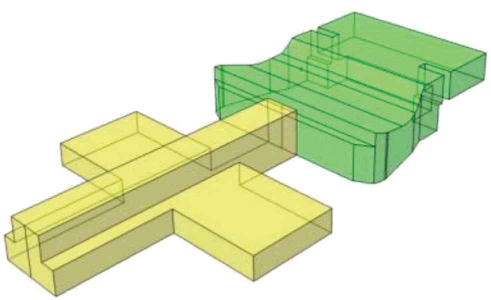
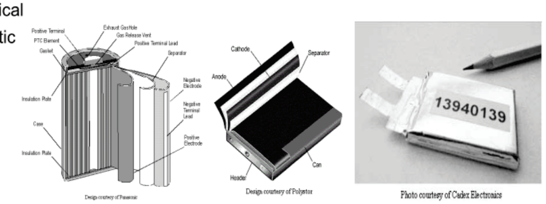
WP 3 - Concept & Feasibility Study

- Definition of interfaces
- Battery managment system
- Cell selection
- Package room/battery housing





- Cells are available in a variety of packages :
  - Cylindrical
  - Prismatic
  - Pouch



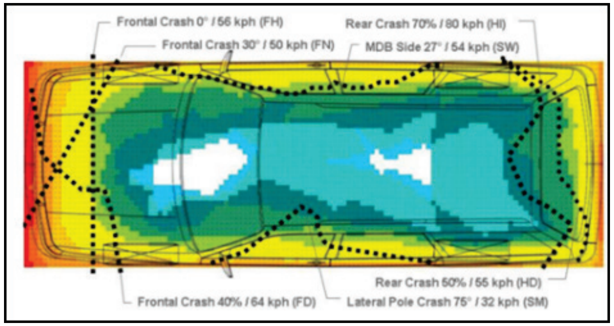
	Cylinder	Prismatic	Pouch
Energy Density	Medium	High	Highest
Mechanical Stability	High	Medium	Low
Thermal Performance	High	Highest	Medium
Space Utilization	Low	High	Highest
Manufacturing cost	High	Medium	Low
Pressure Withstand	High	Medium	Low

Key:
- Desirable
- Acceptable
- Undesirable

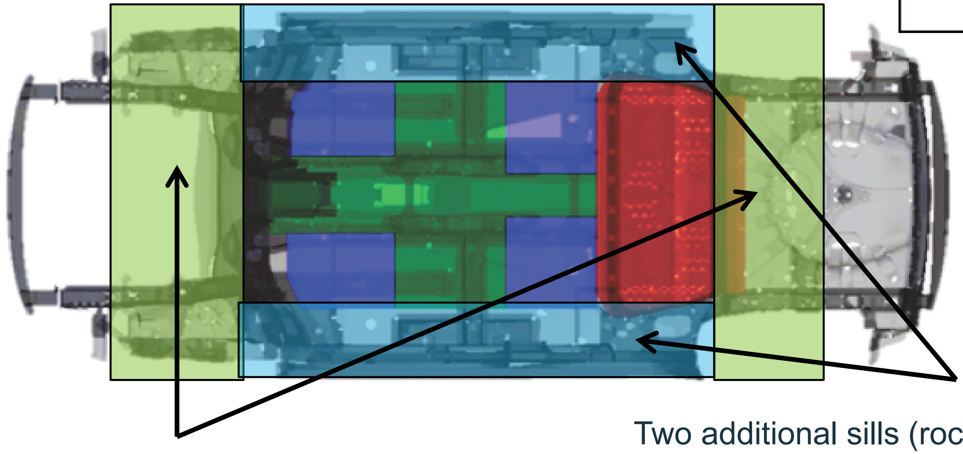
•Cell package selection is a trade-off, no one package is universally best

Searching for a safe Space that meets the Requirements

- Combining accident statistics with SLC CAD
- Possible structural solution of EV body



Source: Justen et. al



1

Given stiff front (conceptual block) we can justify similar design concept in the rear of vehicle. This gives us two stiff, crashworthy energy absorbing and anti-penetration limits of passengers cabin

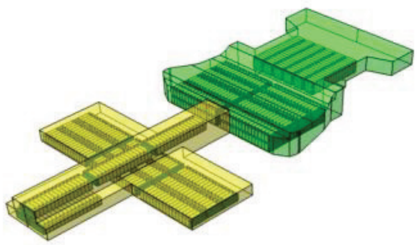
2

Two additional sills (rocker panels) add additional stiffness (torsional stiffness in the first place). Like in current designs rocker panels work as important side impact energy absorbers. Side impact load transferring mechanism (to the non-stuck side) must be modified.

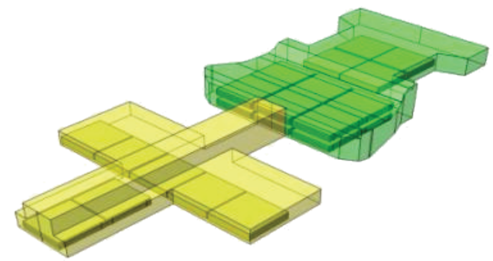
This opens a way to flexible platform design (sedan/coupe – substantial bending stiffness of floor panel).

Concepts

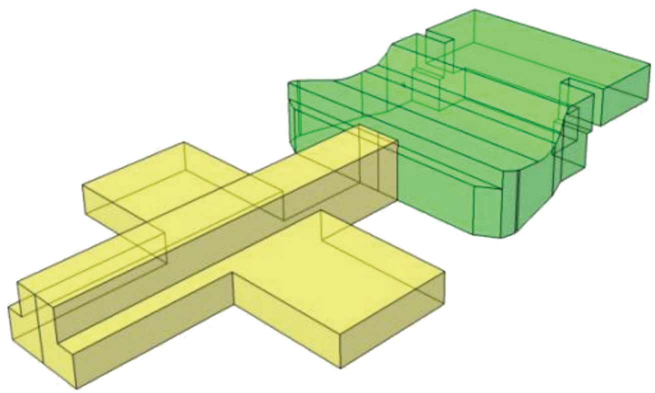
- Different investigated concepts (Metal Case vs. Pouch) within the maximum package

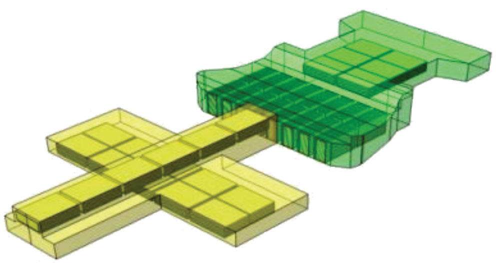


MC 1 battery system

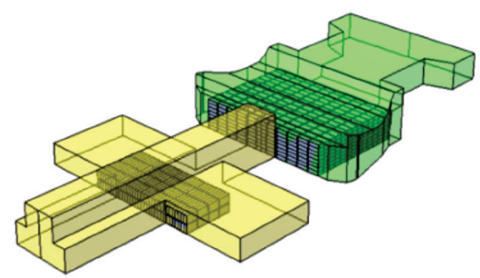


P3 battery systems





P1 battery system



MC 2 Battery System

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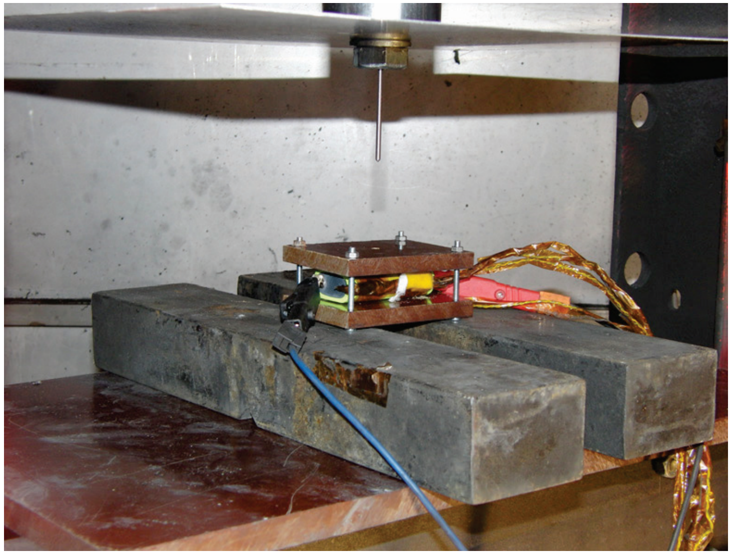
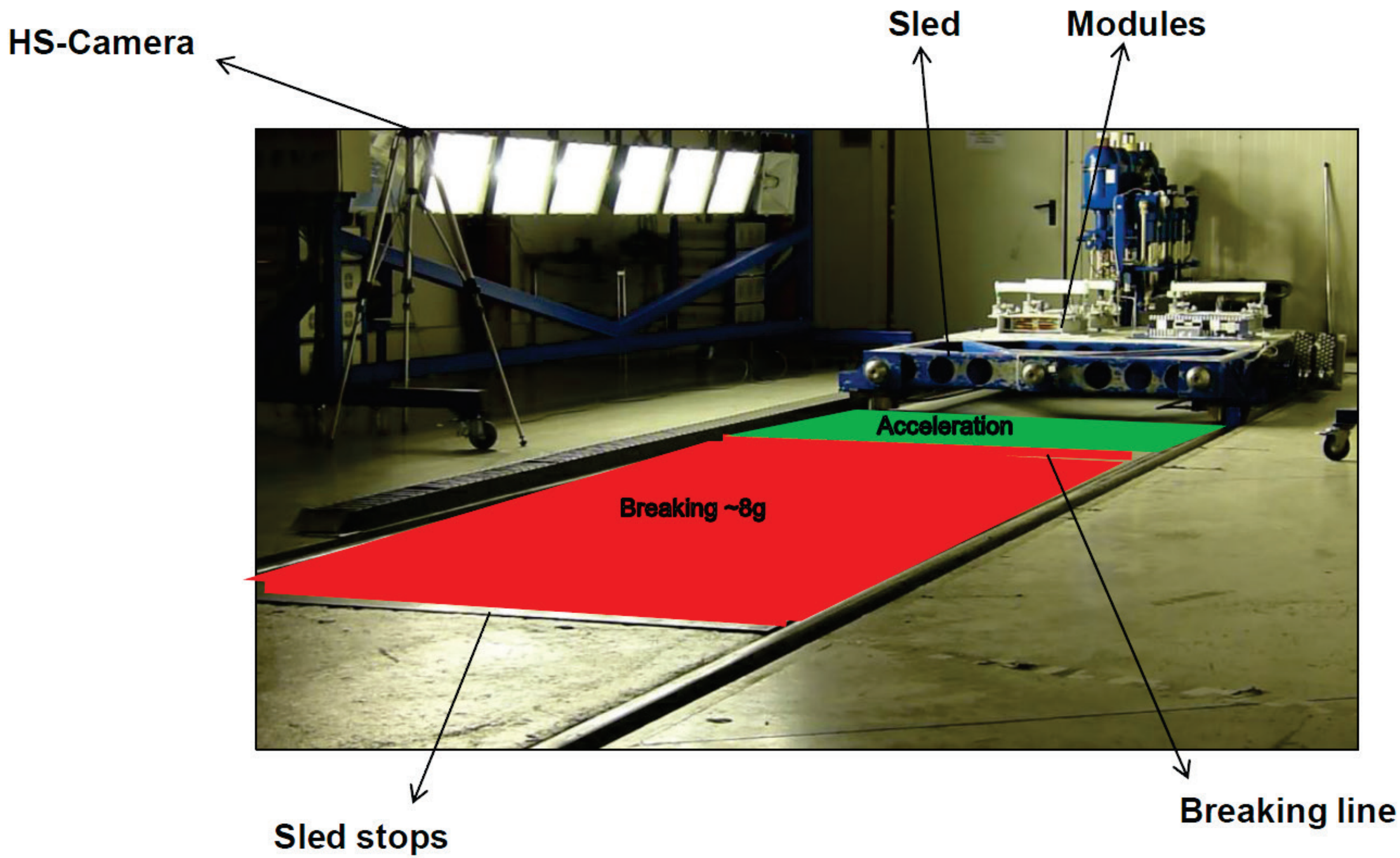
WP 4 - Risk Assessment

- Theoretical risk and failure analysis (e.g. FMEA)
- Experimental analysis (e.g. safety tests)

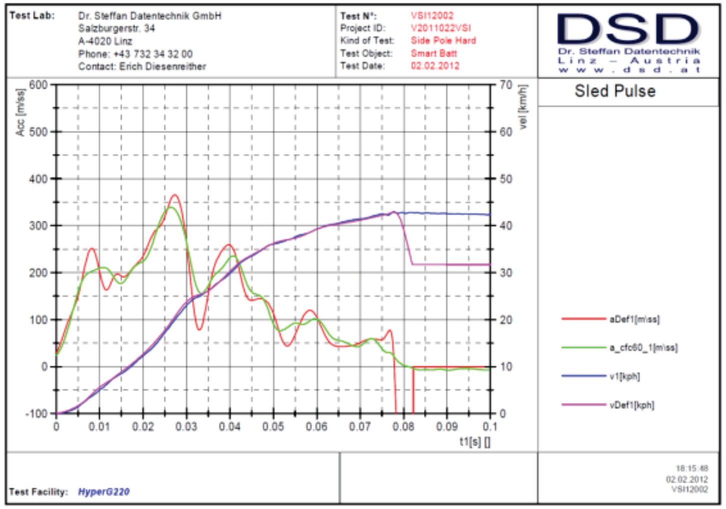


Sledge Tests

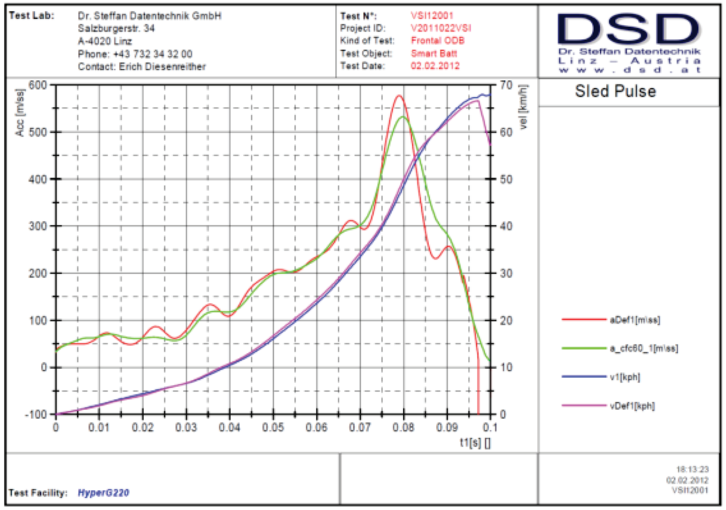


Acceleration pulses

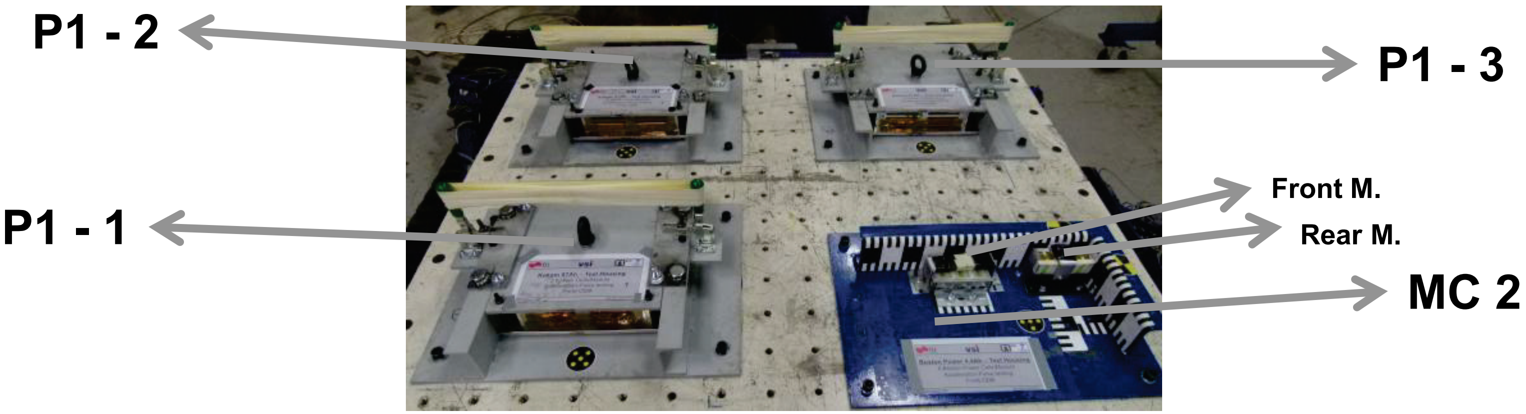
Front ODB acceleration test
- Data of acceleration out of SLC Model



Pole acceleration tests
- Data of acceleration out of SLC Model



Module	FrontODB	Side Pole-Hard	Side Pole-Standard
P3 - 1 (2Cells)	Same cells for all tests – Thermal-Shock-Cycling-Cells		
P3 - 2 (2Cells)	Same cells for all tests – module checked after test 2		
P3 - 3 (2Cells)		2 New Cells changed before the test	
MC 2 (6Cells)	Same cells for all tests – 2Thermal-Shock-Cycling-Cells - 4 New Cells		
MC 2 (6Cells)		6 cells changed before the test	



Conclusion WP 4

- No reaction because of acceleration
- No damage of the module housing
- No damage of the cells
- Both cell types passed this test

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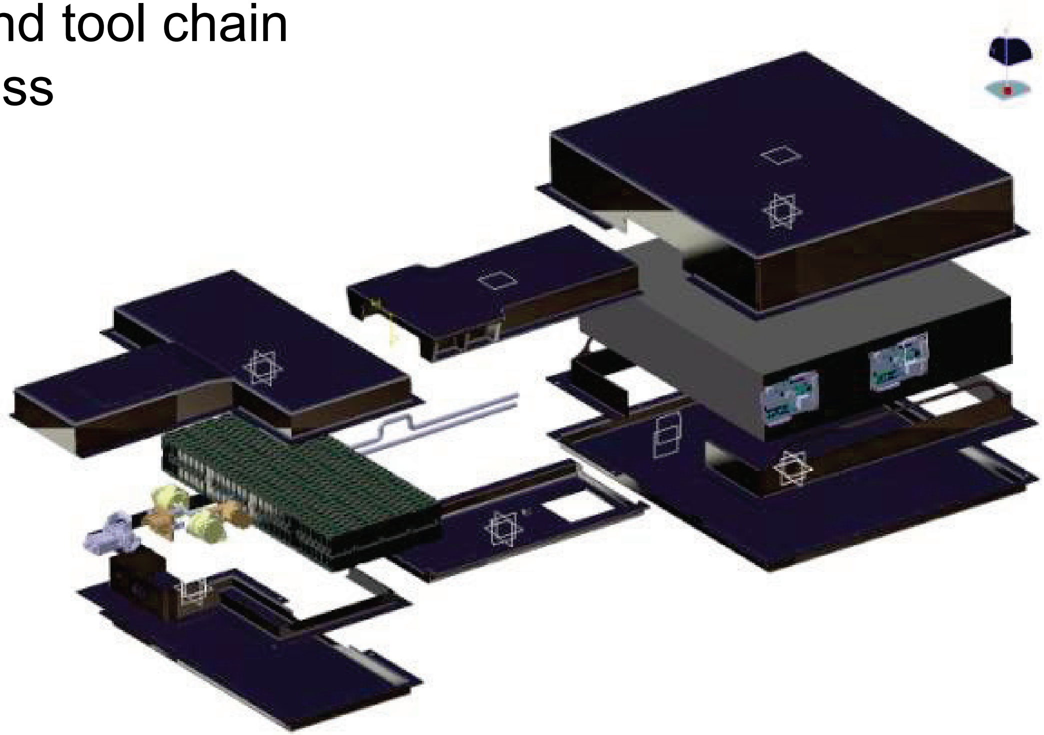
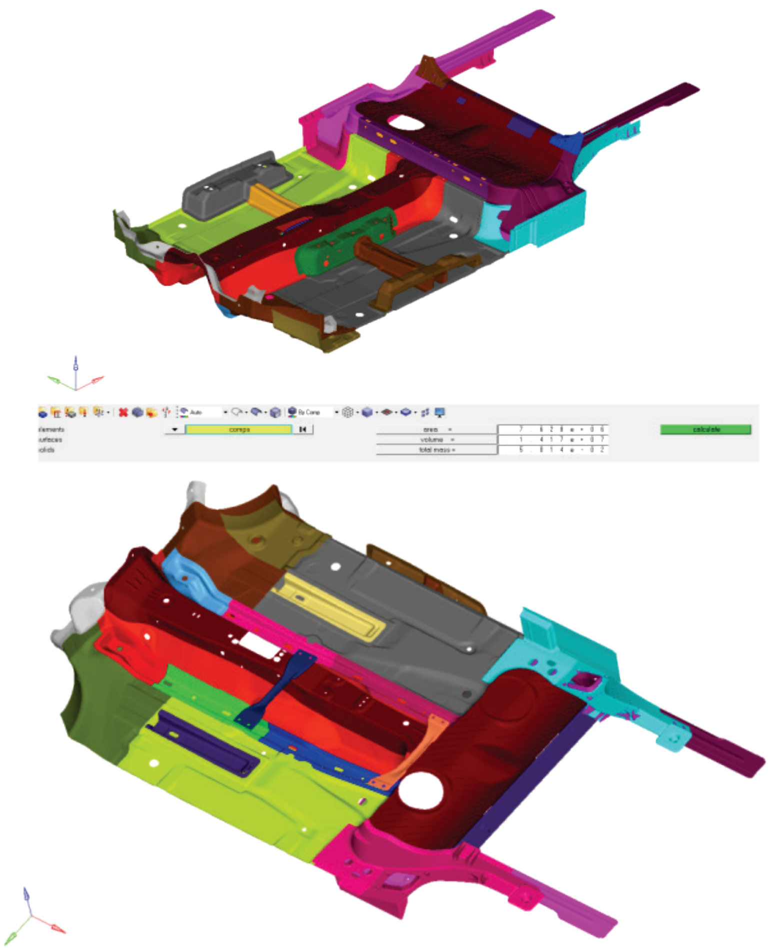
WP 5 - Design & Development

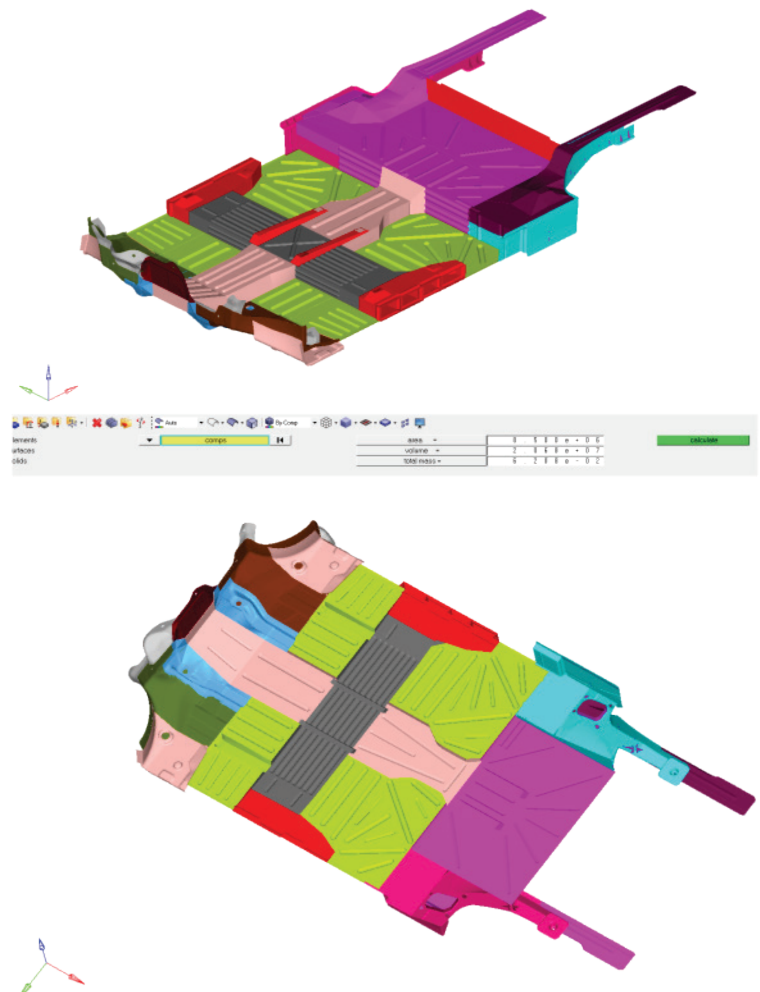
- Design of housing & mounting/simulation based optimization
- Design of modules
- Total weight of 160 kg achieved (goal was 169 kg)
- General workflow and tool chain for the design process



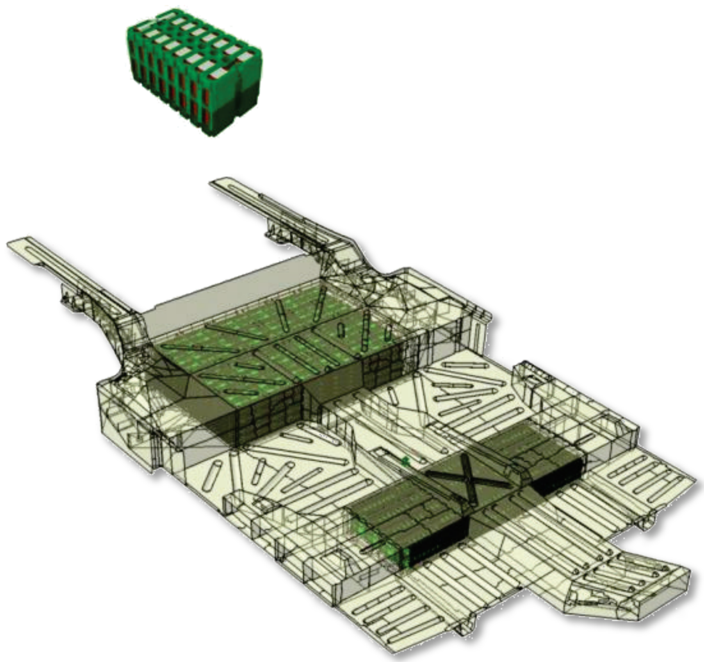
Re-designed floor panel

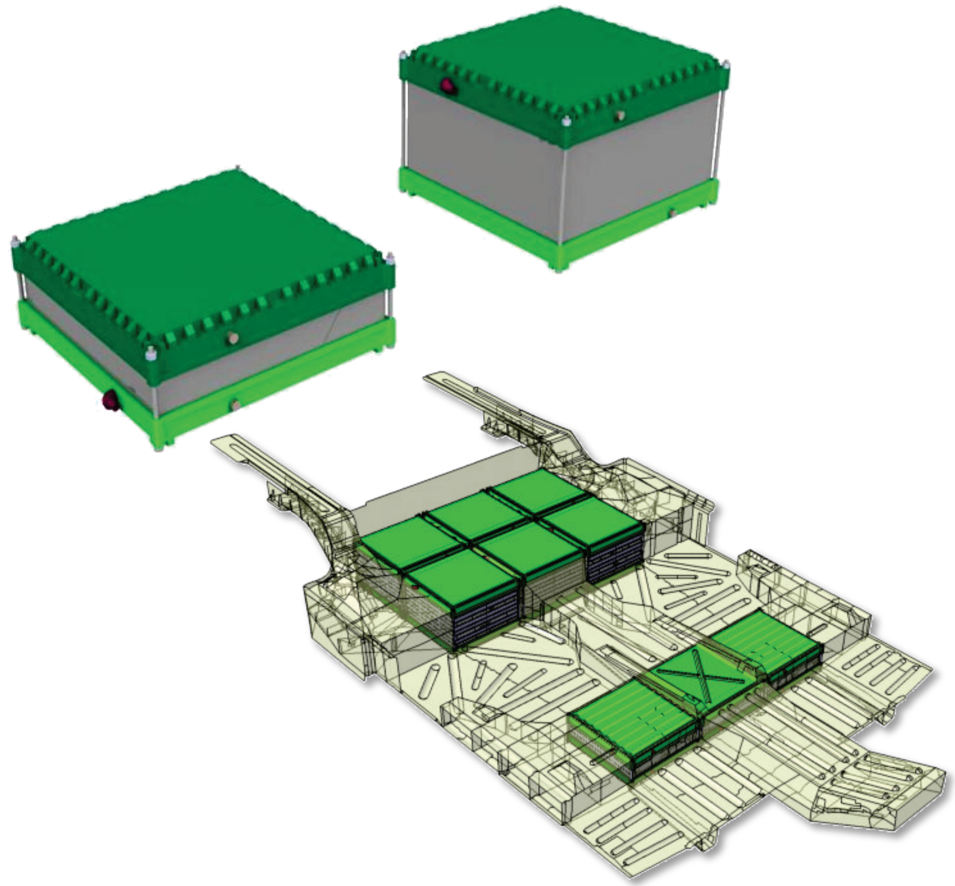
Floor Panel: 50.1 [kg]





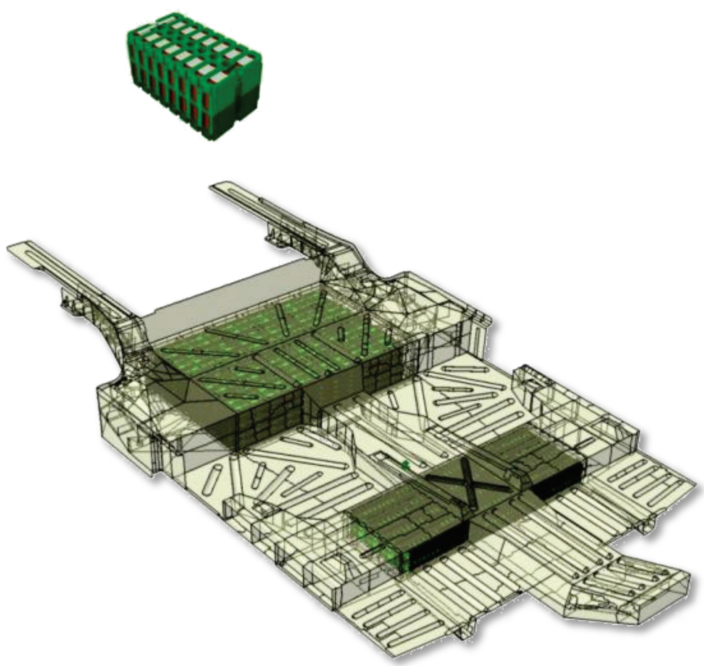
Prismatic vs. Pouch Cell





	Prismatic	Pouch cell
weight ratio:	13,3 %	18,1 %
grav. energy density:	158 Wh/kg	146 Wh/kg

Prismatic vs. Pouch Cell



	Prismatic	Pouch cell
weight ratio:	13,3 %	18,1 %
grav. energy density:	158 Wh/kg	146 Wh/kg

Assembling

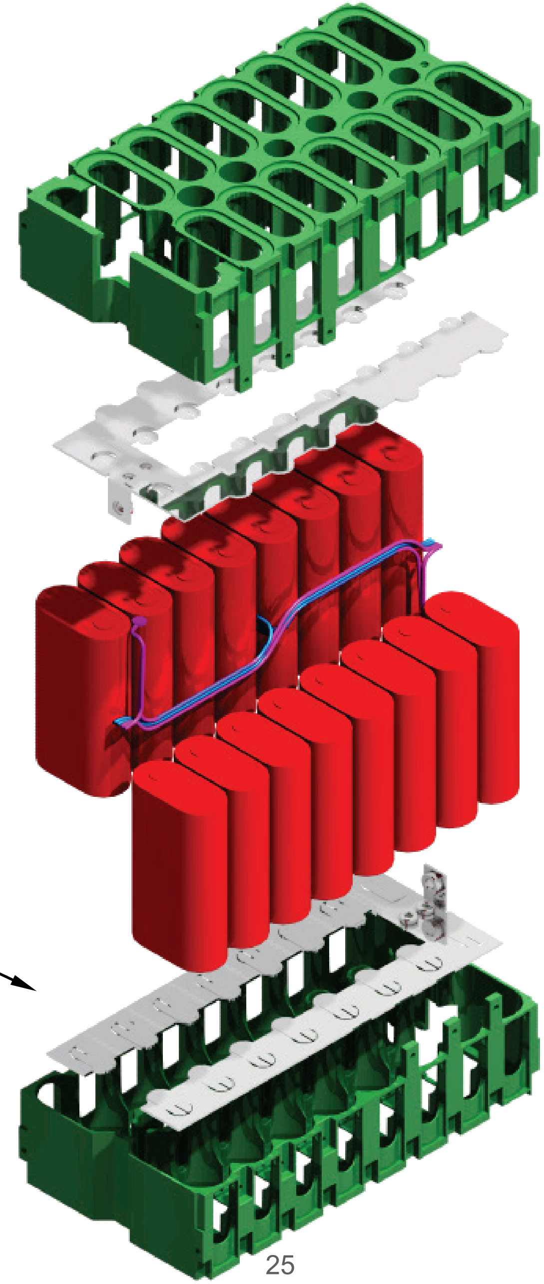
top-cover

connector (+)

Prismatic Cell

connector (-)

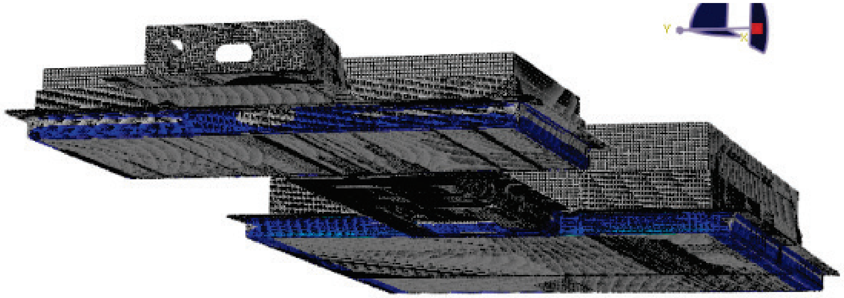
bottom-cover



Technical Details

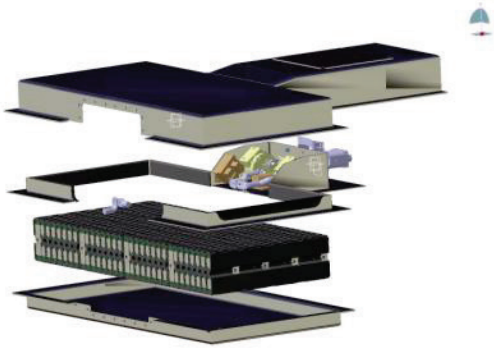
Al hybrid foam sandwich structure

- Maximum stiffness
- Lightweight design
- Ground protection



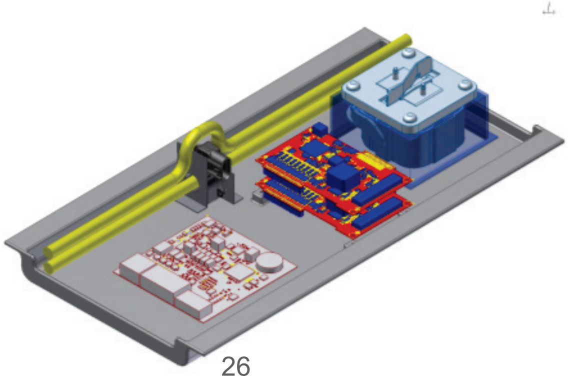
Integrated „Plug balcony“

- Easy to reach from inside
- Fully integrated



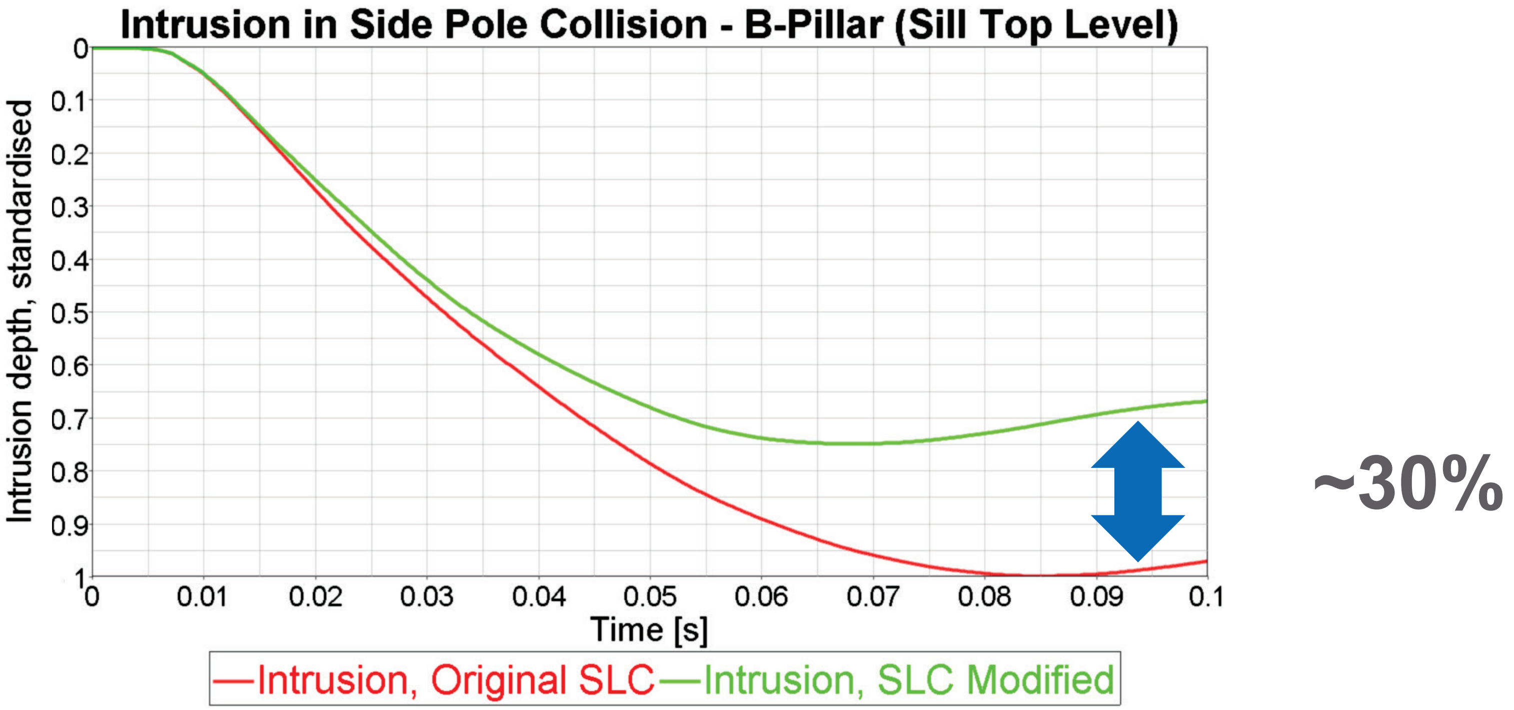
Aluminium die-cast tunnel

- High grade of geometrical flexibility
- Integrates electrical components



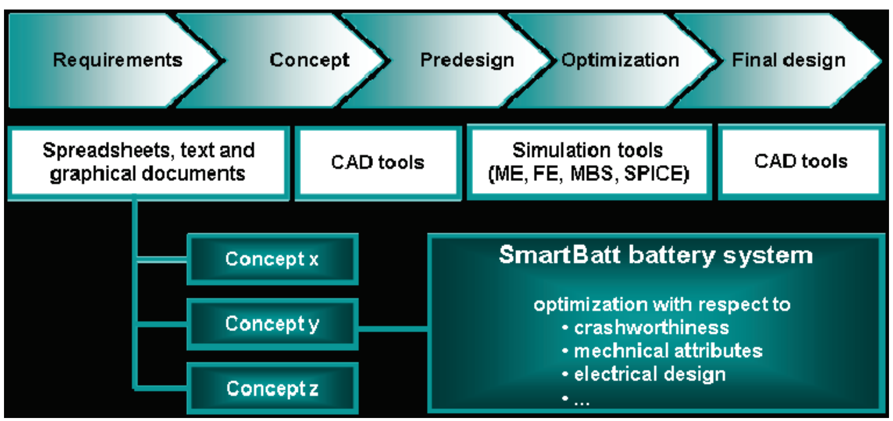
Improvements for side pole test

- Not only a safe battery housing → also improvements on vehicle level
- Example: Intrusion depth (based on LS Dyna simulation)



Tool Chain

- Interdisciplinary communication is necessary
- No simple tool chain for such complex and interdisciplinary projects
  Actually it is a matrix with a set of different tools for the different tasks
- Not only highly sophisticated computer aided engineering tools, like finite element (FE) and computer aided design (CAD) software important but also standard office software, e.g. spreadsheets
- CAD was the "basic language" in the project



Discipline	Requirements / concepts	Predesign	Optimization loops	Fine tuning	Final Design
Crash worthiness	Spreadsheet	CAD	ME	FE	CAD
Mechanical attributes	Spreadsheet	CAD	FE	FE	CAD
Driving dynamics	Spreadsheet	CAD	MBS	MBS	CAD
Electrical components	Spreadsheet	CAD	SPICE/Schematics	SPICE/Schematics	CAD
Risk analysis	Spreadsheet	Spreadsheet	Spreadsheet, mind mapping	Spreadsheet, mind mapping	Spreadsheet, mind mapping

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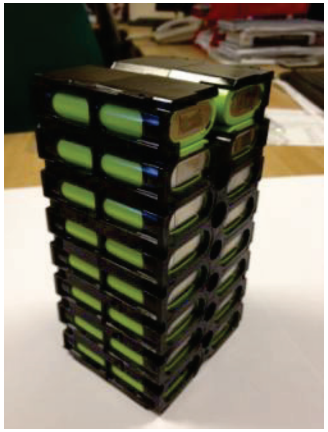
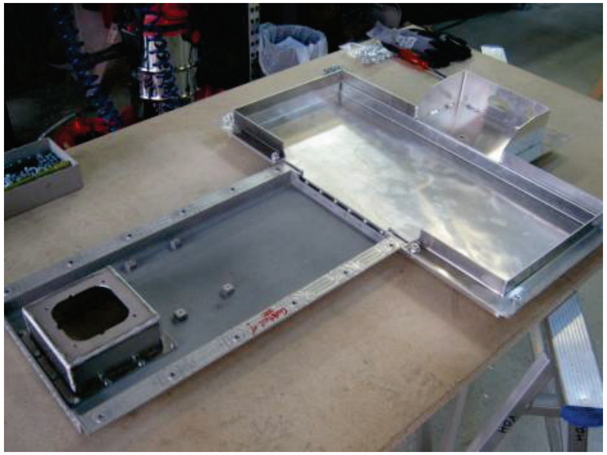
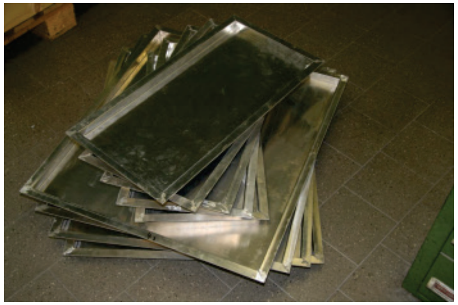
WP 6 - Hardware Build-Up & final Validation - AIT

- Build-up of a fully equipped evaluation model
- Build-up of an empty housing for test-reason
- Testing on pack level
    - Overtemperature
    - Overcharge, -discharge





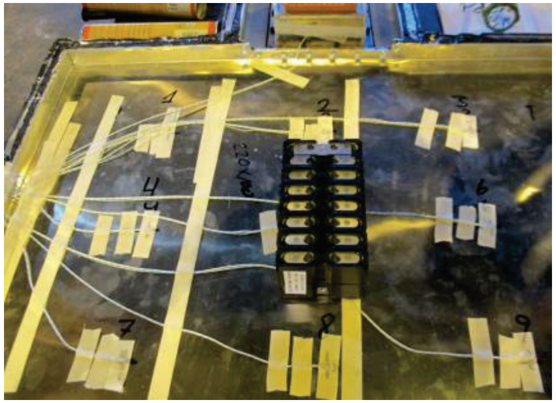


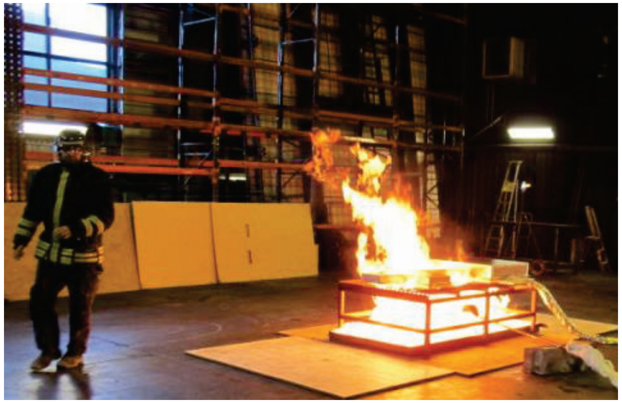
WP 6 - Hardware Build-Up & final Validation - Ricardo

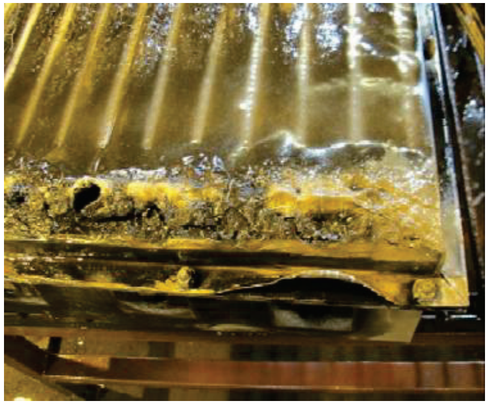
- Adoption of hard- and software to specific application
- New generation of BMS hardware caused some implementing-problems (hardware review, software updates)
- Setting fully equipped pack into operation
- Conducting operational tests

WP 6 - Hardware Build-Up & final Validation - SP

- Fire Test According to Future R100
  - Equipped with thermocouples, one battery module and bricks simulating thermal capacity
  - Placed on a grating table above fuel pan
  - Exposed to flames for a total of 130 s
  - Validating simulations

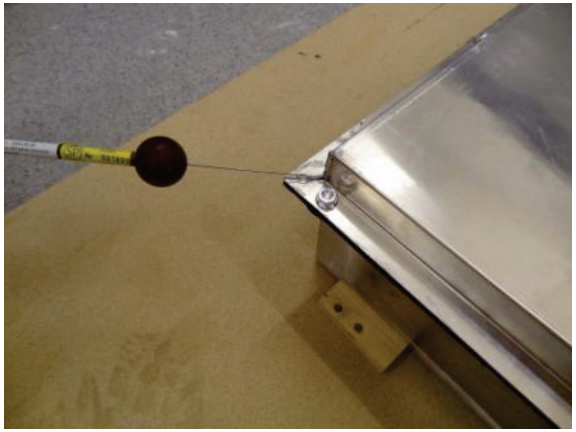


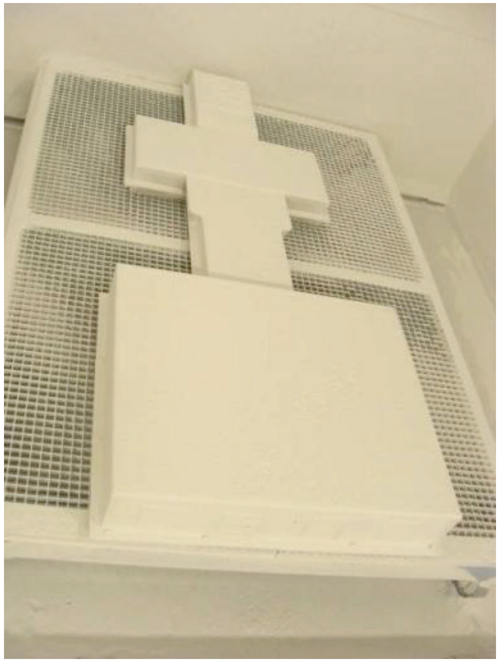




WP 6 - Hardware Build-Up & final Validation - SP

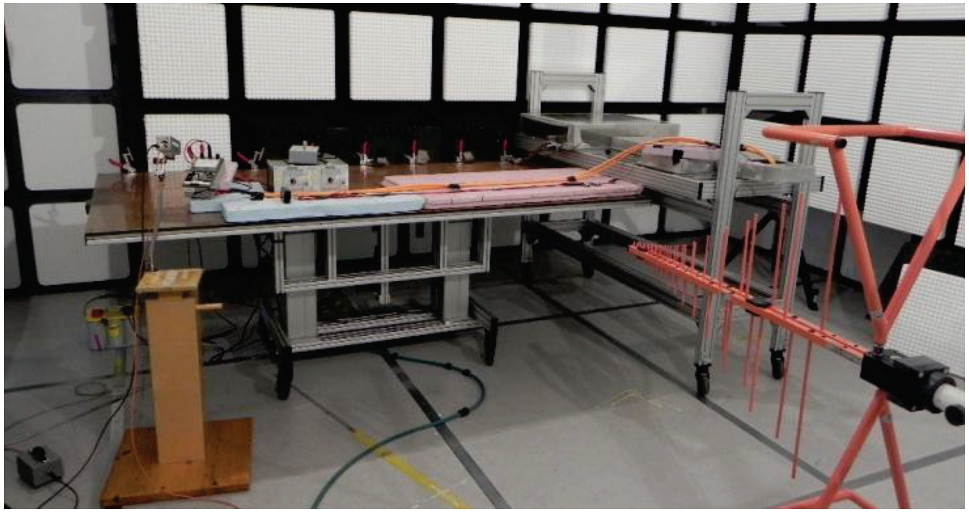
- IP Evaluation Test
  - Classification of degree of protection according to ISO 20653:2006, IP6K9K
  - Empty battery housing prototype
  - Exposed to test probe, dust and water



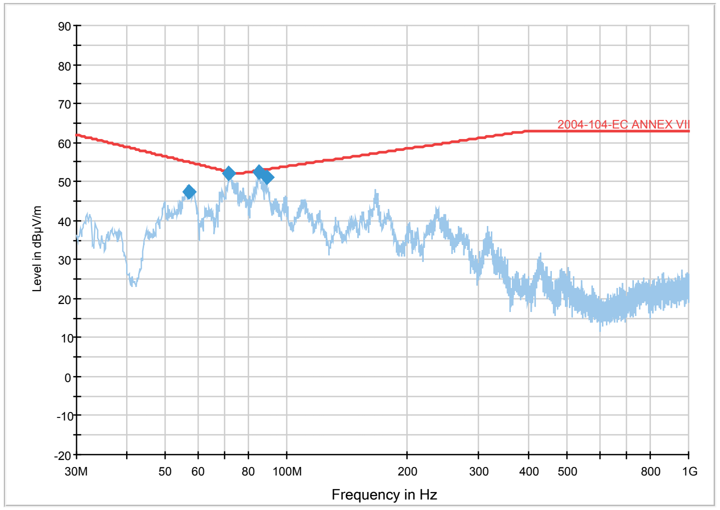


WP 6 - Hardware Build-Up & final Validation - SP

- EMC Test
  - Radiated emission and radiation immunity
  - System running in normal operation with no load on HV outputs
  - Tested according to Functional Status Classification A

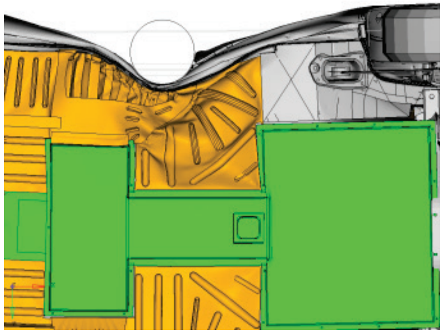


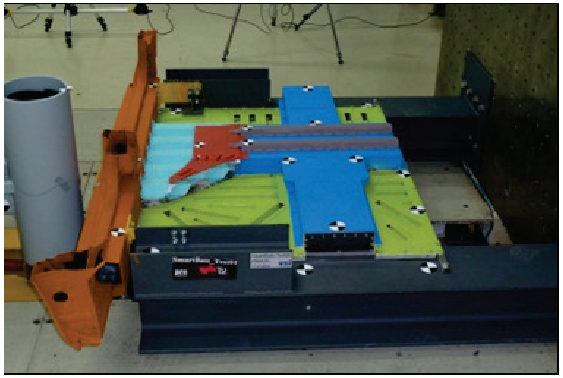
_E_radiated_2004-104-EC Annex VII

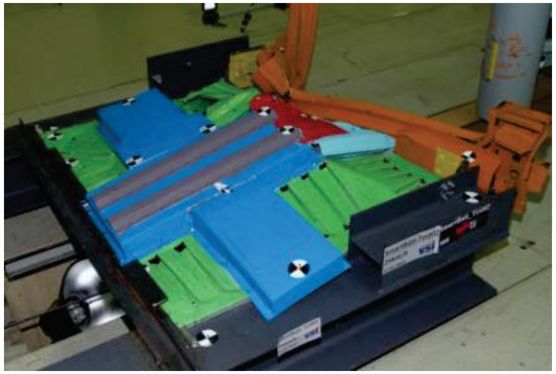


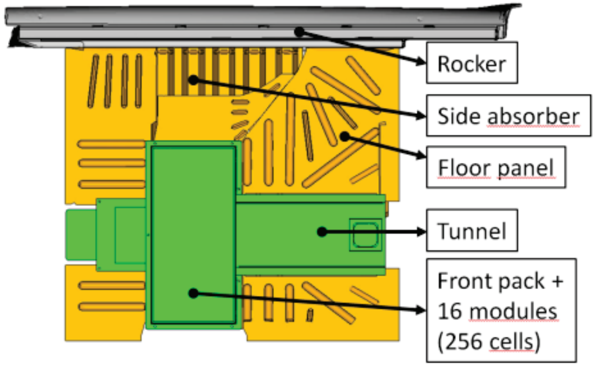
WP 6 - Hardware Build-Up & final Validation – TU Graz

- Crash Test
  - Complete floor structure assembled
  - Use of battery cell dummies
  - Validating simulations
  - Real crash test was similar to simulation after some improvements









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WP 7 - Assessment

➢ Weight optimization

- Performed analysis regarding energy consumption due to less weight of the battery system
- Performed analysis on driving range improvements due to more battery capacity
- Three different vehicle types were compared in standardized driving cycles and performance tests (NEDC, FTP 72 and Artemis cycle)

➢ Cost savings

- The concept is suitable for the use in mass production
- Cost outlook indicates potential in price reduction for cells
- Components depending on volume sizes

➢ Impact on standardization

- Standardization concerning EVs is performed within ISO/TC 22/SC21 and IEC/TC 69
- UNECE/REESS amendment to R100 Battery Electric vehicle safety for Lithium Ion batteries developed and signed, interim from 1/3 2013, probably into force 1/3 2014

➢ Impact on replaceable-energy-storage-system concepts

- Reviewed standardization of cells, modules, battery management system, electrical connectors and communications and battery enclosure
- Imminently no standardization in sight

WP 1: Project Management

WP 2: Specification Analysis / Requirements

WP 3: Concept & feasibility Study

WP 4: Risk Assessment

WP 5: Design & Development

WP 6: Hardware Build-Up & final Validation

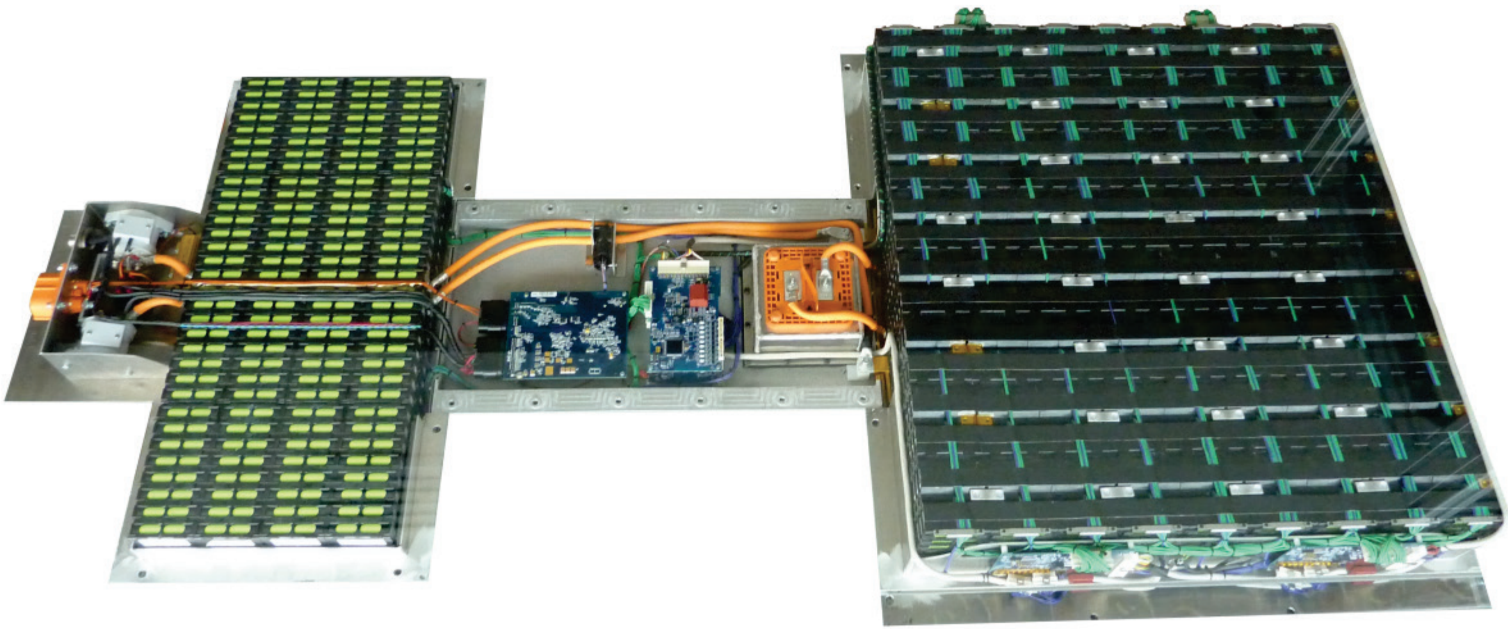
WP 7: Assessment

WP 8: Exploitation

WP 8 - Exploitation

- Knowledge Transfer
  - To electric vehicle community and broader public
  - Papers / Conferences
  - Other EU projects
- Promote Results
  - Website WP4/WP6
  - "Battery Integration Workshop" in May 2012 in Brussels
  - Fire fighter workshop in Austria
  - 5 papers in different conferences published
  - Exhibition of the demonstrator at the EEVC 2012 in Brussels
- Input for Regulations and Standards
  - ISO TC22/SC21 and UNECE R100 amendment

http://www.smartbatt.eu/



Project Coordination
Hansjörg Kapeller
AIT Austrian Institute of Technology GmbH
Giefinggasse 2 | 1210 Vienna | Austria
T +43(0) 50550-6606 | F +43(0) 50550-6595
hansjoerg.kapeller@ait.ac.at
http://www.ait.ac.at