HELIOS

Cell testing in HELIOS for parameterization of digital twins

COLLABAT

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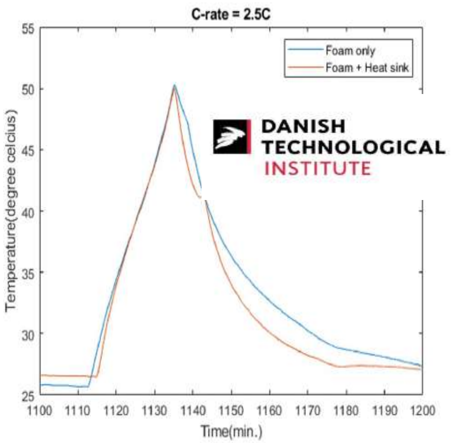
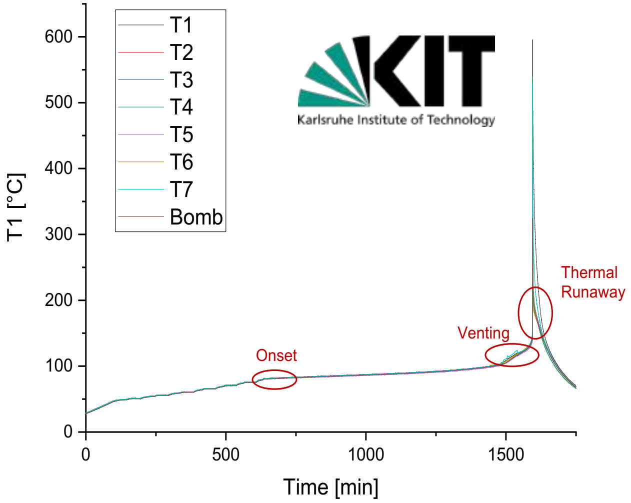
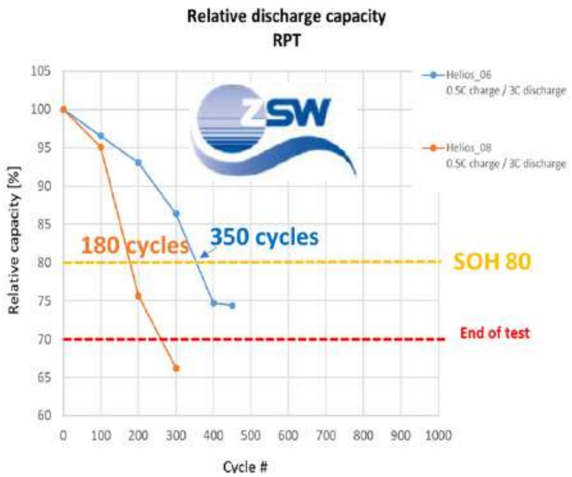
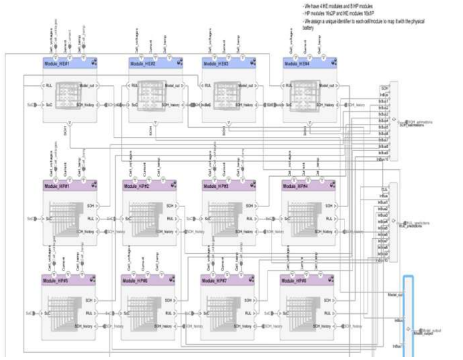
AARHUS UNIVERSITY









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HELIOS Project Overview

High-performance modular battery packs for sustainable urban electromobility services

- Funded under EU Horizon2020
  total EC grant approx. 10 Mio €
- Runtime Jan 2021 to Dec 2024 (48 months)
- 18 consortium partners from 8 countries
- Website: www.helios-h2020project.eu
- Project Coordinator:

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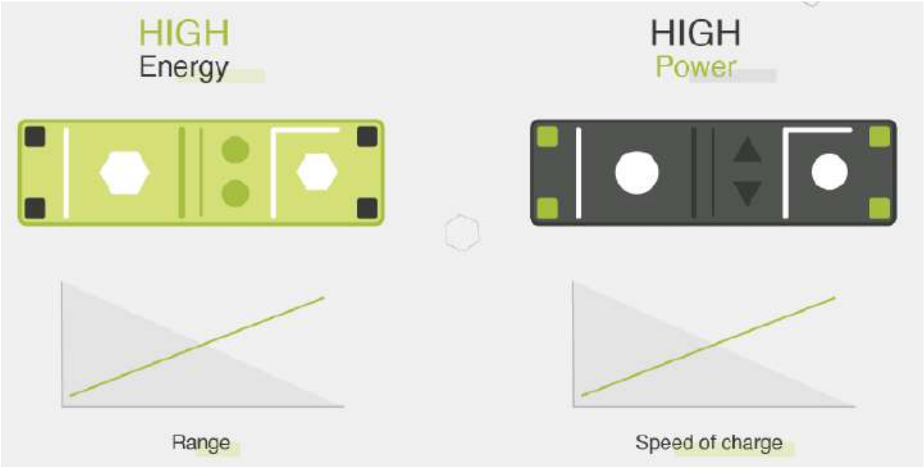
HELIOS General Project Objectives

- new concept of smart, modular and scalable battery pack for a wide range of electric vehicles:
  - *2 use cases for prototypes: small city car and full-size electric bus*
- improved performance, energy density, safety, lifetime and LCoS (Levelized Cost of Storage)
- optimised EV charge (incl super-fast charging) and discharge procedures and predictive maintenance schedules
- creating new designs and processes for ease of battery reuse in 2nd-life and recycling at EoL, contributing to circular economy

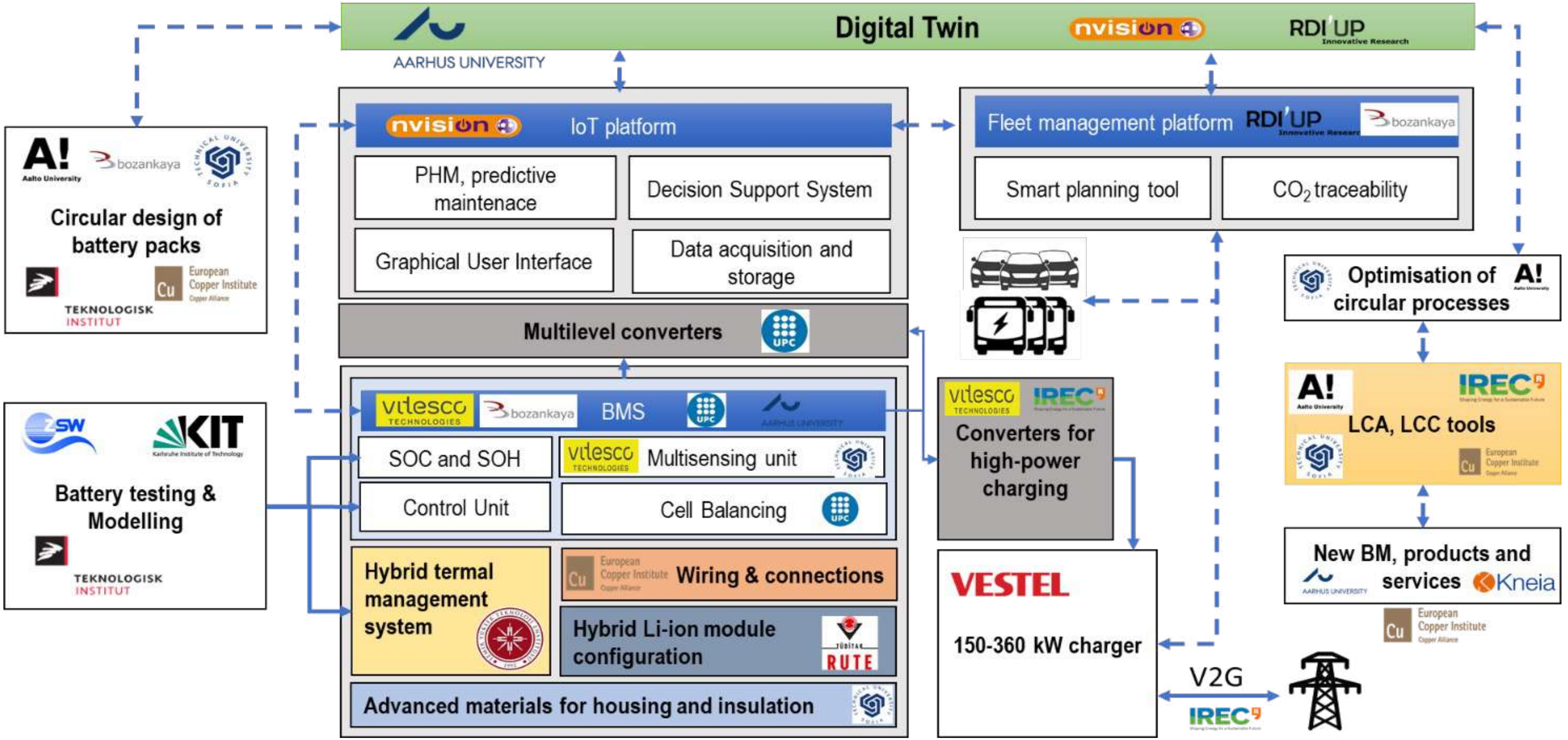
i-MiEV at AU



Demonstrator

Sileo S12 e-bus produced by Bozankaya

HELIOS Main building blocks



HELIOS Cell Testing

Key objectives

- *Determination of the coupled electrochemical, thermal and safety data either as required input parameters for the modelling or as validation data for the simulation results*
- *Elucidating ageing processes by cyclic and calendaric ageing study and post-mortem analysis*

Electrochemical and Thermal Characterization

Cycling Test	Ch	Dch
Adiabatic Cycling Test (ARC)	0.5C	0.5C, 1C, 1.5C
Isothermal Cycling Test	0.5C	0.5C, 1C, 1.5C, 2C, 2.5C, 3C
Specific Heat Capacity		
Heat Transfer Coefficient	0.5C	0.5C, 1C, 1.5C
Thermal Conductivity or Thermal Resistance	HE cells	

Cycling Test	Ch	Dch
Adiabatic Cycling Test (ARC)	1C, 3C	1C, 2C, 3C
Isothermal Cycling Test	1C, 3C	4C, 5C
Specific Heat Capacity		
Heat Transfer Coefficient	1C	1C, 2C, 3C
Thermal Conductivity or Thermal Resistance	HP cells	

Safety Testing

	SOC
Thermal abuse test	
Heat-Wait-Seek (ARC)	100%
Heat-Wait-Seek (ARC)	75%,50%,25%, 0%
Ramp Heating (autoclave)	100%
External fire	100 %
Electrical abuse test	
Overcharge	>100%
Overdischarge	<0%
External Short Circuit	100%
Mechanical abuse test	
Nail penetration	100%, 75%, 50%, 25%, 0%
Mechanical abuse test	
Crush	100%
Mechanical Shock	100%

Ageing Study

Cyclic Ageing

HE cells

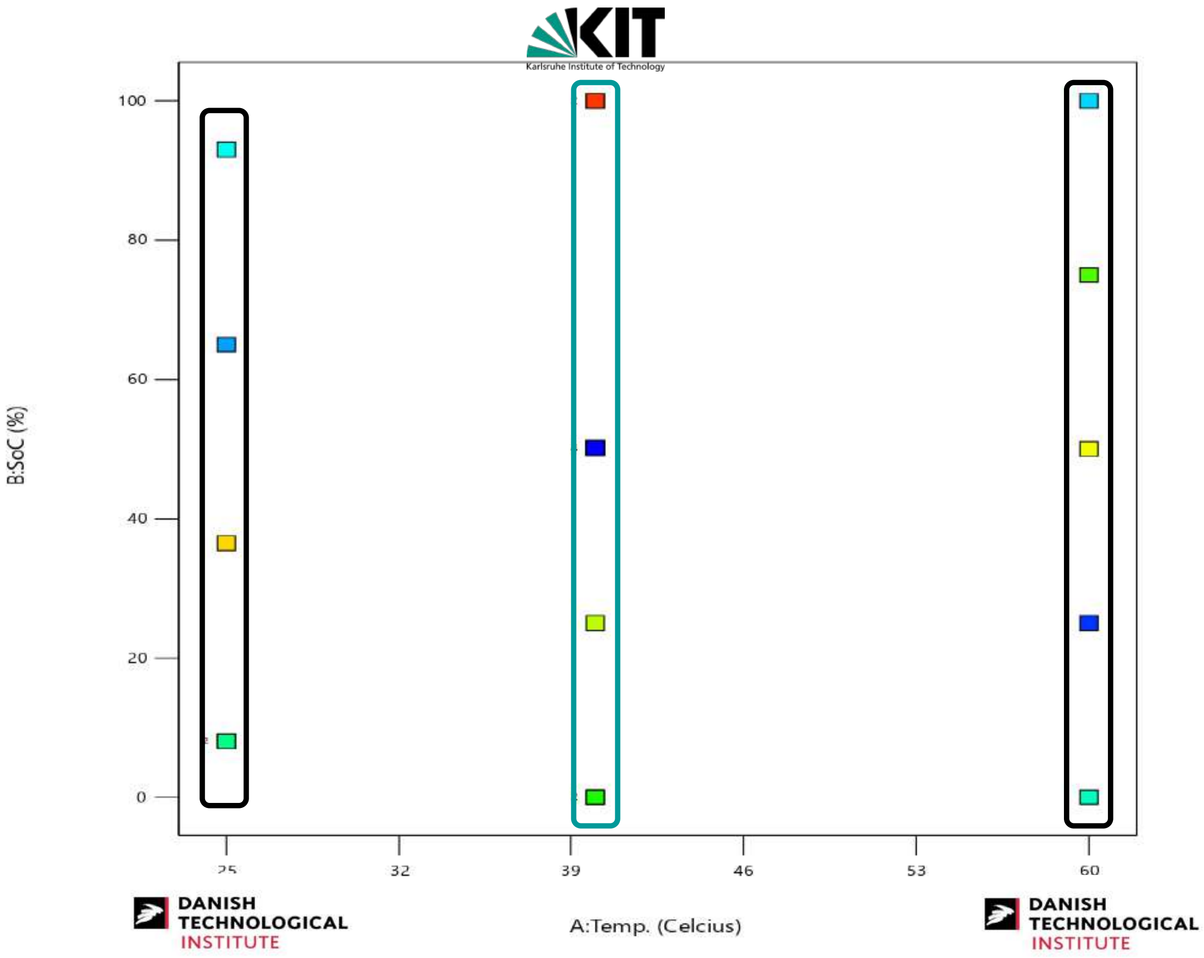
	Ch/Dch	SOC limits		Temp [°C]
High temp	0.5C/1C	0%	100%	50
High temp	0.5C/1C	0%	100%	40
Normal temp	0.5C/1C	0%	100%	25
Normal temp	1C/1C	0%	100%	25
Fast discharge	0.5C/3C	0%	100%	25

HP cells

	Ch/DCh	SOC limits		Temp [°C]
Fast charge	2.5C/1C	0%	100%	25
Fast charge	5C/1C	0%	100%	25
Fast discharge	1C/5C	0%	100%	25

Ageing Study

Calendaric Ageing



1st delivery of cells: 40 cells on M6
2nd delivery of cells: 300 cells on M24

significant changes had to be made to the aging matrix to optimize use of resources within the time left in the project

DOE approach for matrix reduction: 19 instead of 38 tests

Temperature and SOC values as proposed by DoE approach

Temperature	SoC values(%)				
25 °C	7.5%	37%	65%	93%*	
40 °C	0%	50%**	75%	100%*	
60 °C	0%	25%	50%	75%	100%

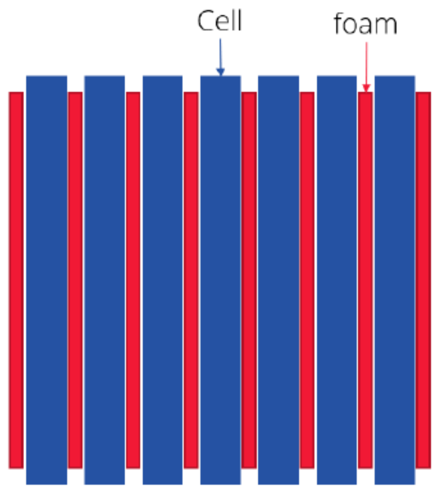
* 2 replicates
**4 replicates

Expected duration of tests: 12 months calendaric aging

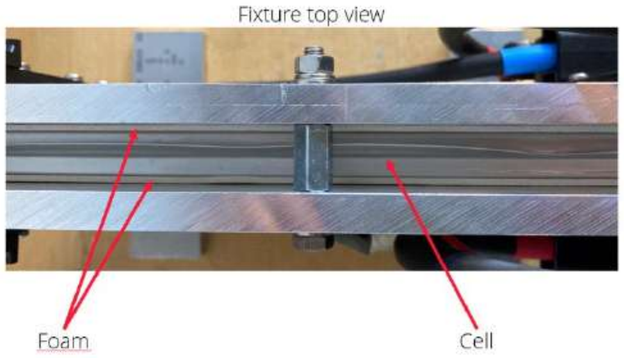
Map of SoC and Temperature points for testing based on DoE approach using design expert 13

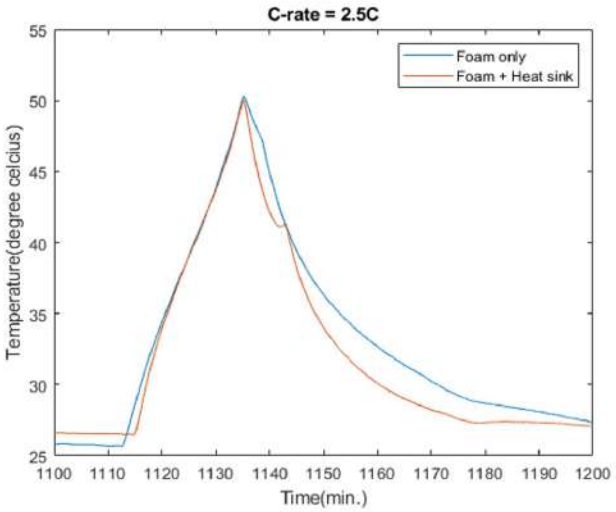
Improvement of fixture design

Version 1

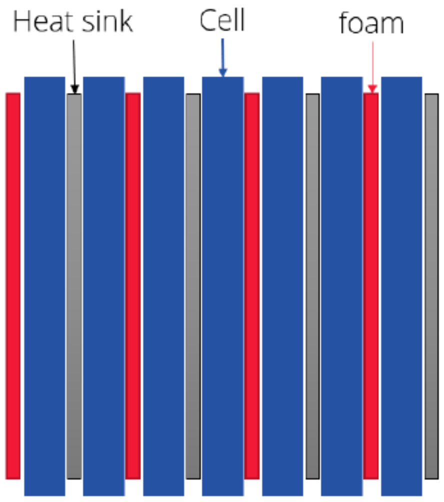


Issues with Heat retention at high C-rates

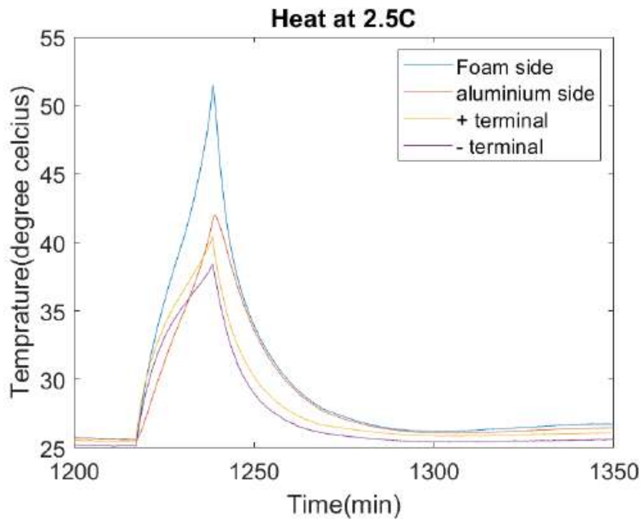




Version 2



Reduced heat retention



Important input for TMS design in WP3

time to reach 30 °C from 50 °C reduced from around 37 min with the pure foam setup to around 25 min for the foam heat sink setup

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Measurements

- ✓ Cell heat generation and dissipation
- ✓ Surface temperature homogeneity
- ✓ Voltage/Current/Temperature
- ✓ Efficiency
- ✓ Specific heat capacity
- ✓ Thermal conductivity or thermal resistance
- ✓ Heat transfer coefficient
- ✓ Reversible and irreversible heat effect

Tools

- ✓ Calorimeters (ARC, Isothermal, Tian-Calvet)
- ✓ Thermal Imagers
- ✓ Constant Temp. Chambers
- ✓ Temperature Sensors
- ✓ Heat Flux Sensors
- ✓ Heater mats
- ✓ Transient Hot Bridge
- ✓ Battery Cyclers

Conditions

- ✓ Normal Operation
- ✓ Isoperibolic Operation
- ✓ Isothermal Operation
- ✓ Adiabatic Operation
- ✓ Driving Cycles

Numerical Simulations

Validation Studies at Cell Level

Multi-Scale Multi-Dimensional Model

- ✓ ECM
- ✓ NTGK

Safety Testing

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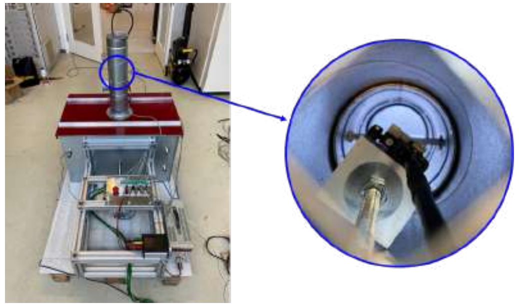
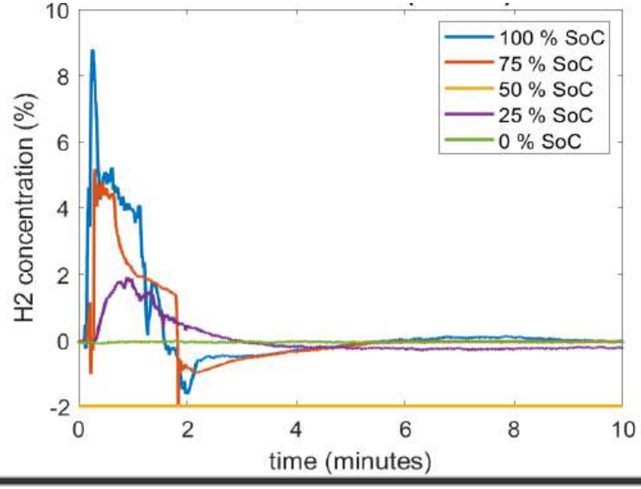
Autoclave and Crush test at ZSW

Autoclave for determination of released thermal runaway energy

Crush Test Device

Nail Penetration with Gas Analysis at DANISH TECHNOLOGICAL INSTITUTE



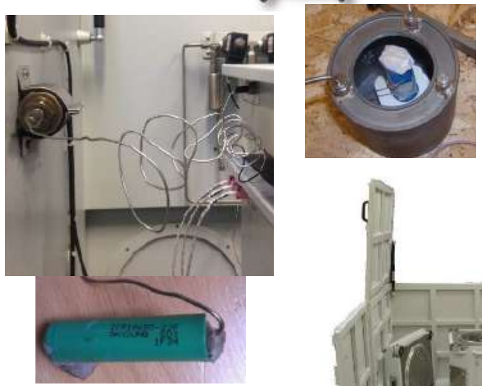


Portfolio of Calorimeters at KIT

Differential scanning calorimeters

Tian-Calvet calorimeters

Small and medium-size ARC



Pressure measurement in ARC

Large-size ARC

Nail penetration test in ARC

Components

1 - 80 mAh

3 - 5 Ah

30 - 75 Ah

Cell Size and Capacity

Measurements

- ✓ Heat-Wait-Seek test to separate exothermal reactions
- ✓ Autoclave or cylinder ramp heating test for heat and gas volume release
- ✓ Standard Thermal abuse (Hot Box, External Fire)
- ✓ Standard Mechanical Abuse (Nail Penetration, Crush, Immersion, Drop, Mechanical Shock, Vibration)
- ✓ Standard Electrical Abuse (Overcharge/Overdischarge)

Tools

- ✓ Calorimeter (ARC), Autoclave
- ✓ Devices for standard abuse tests (Hot Box, Nail Penetration, Crush, External Fire, Immersion, Drop, Mechanical Shock, Vibration, Overcharge)
- ✓ Thermal Imagers
- ✓ Pressure and Heat flux sensors
- ✓ Gas sampling devices and GC/MS analysis

Conditions

- ✓ Abuse Operation

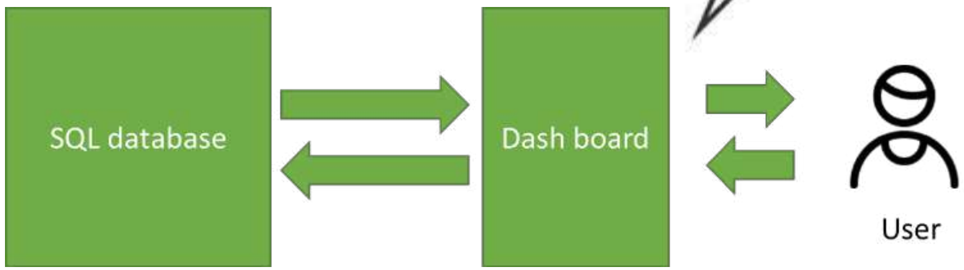
Numerical Simulations

Validation Studies at Cell Level

Multi-Scale Multi-Dimensional Model

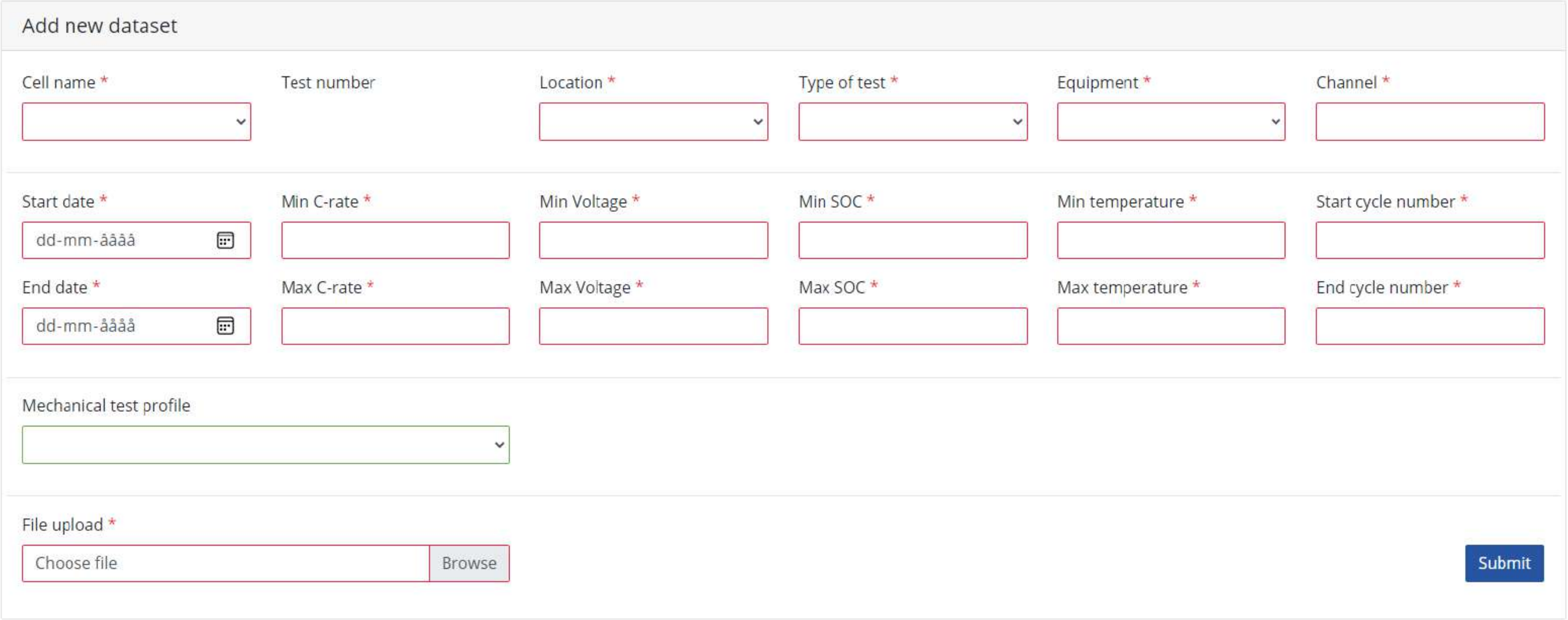
- ✓ ECM
- ✓ NTGK

HELIOS Battery-test data warehouse



Size: 300 GB, will be upgraded as needed.

Purpose: Allow for consistent data structure from all cell tests performed and easy implementation of data for development of algorithms


Add new dataset

Cell name *
Test number
Location *
Type of test *
Equipment *
Channel *

Start date *
dd-mm-åååå
Min C-rate *
Min Voltage *
Min SOC *
Min temperature *
Start cycle number *

End date *
dd-mm-åååå
Max C-rate *
Max Voltage *
Max SOC *
Max temperature *
End cycle number *

Mechanical test profile

File upload *
Choose file
Browse
Submit

HELIOS Tasks and their key objectives

Task 4.1 Cell and battery pack testing

- *Determination of the coupled electrochemical, thermal and safety data either as required input parameters for the modelling or as validation data for the simulation results*
- *Elucidating ageing processes by cyclic and calendaric ageing study and post-mortem analysis*

Task 4.2 Battery modeling

- *Electric, electrochemical, thermal and aging modelling including sensor inputs*
- *Investigation of the correlation of the sensor outputs with impedance, age, state-of-charge, temperature, etc.*

Task 4.3 State estimation

- *Development of State-of-Charge (SOC) and State-of-Health (SOH) estimation and prediction methods*

Task 4.4 Safety management and simulation

- *Development of methods for advanced fault detection, fault tolerance and identification and remaining safe life estimation*

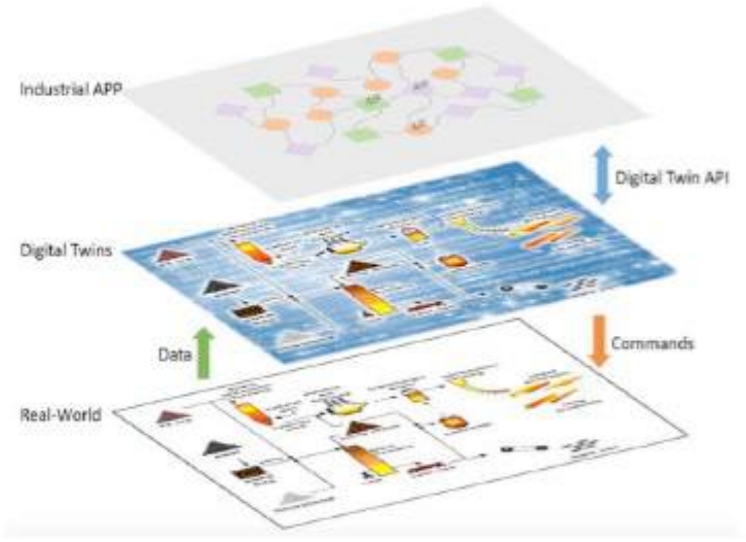
Task 4.5 Complete Model for the development of the digital twin

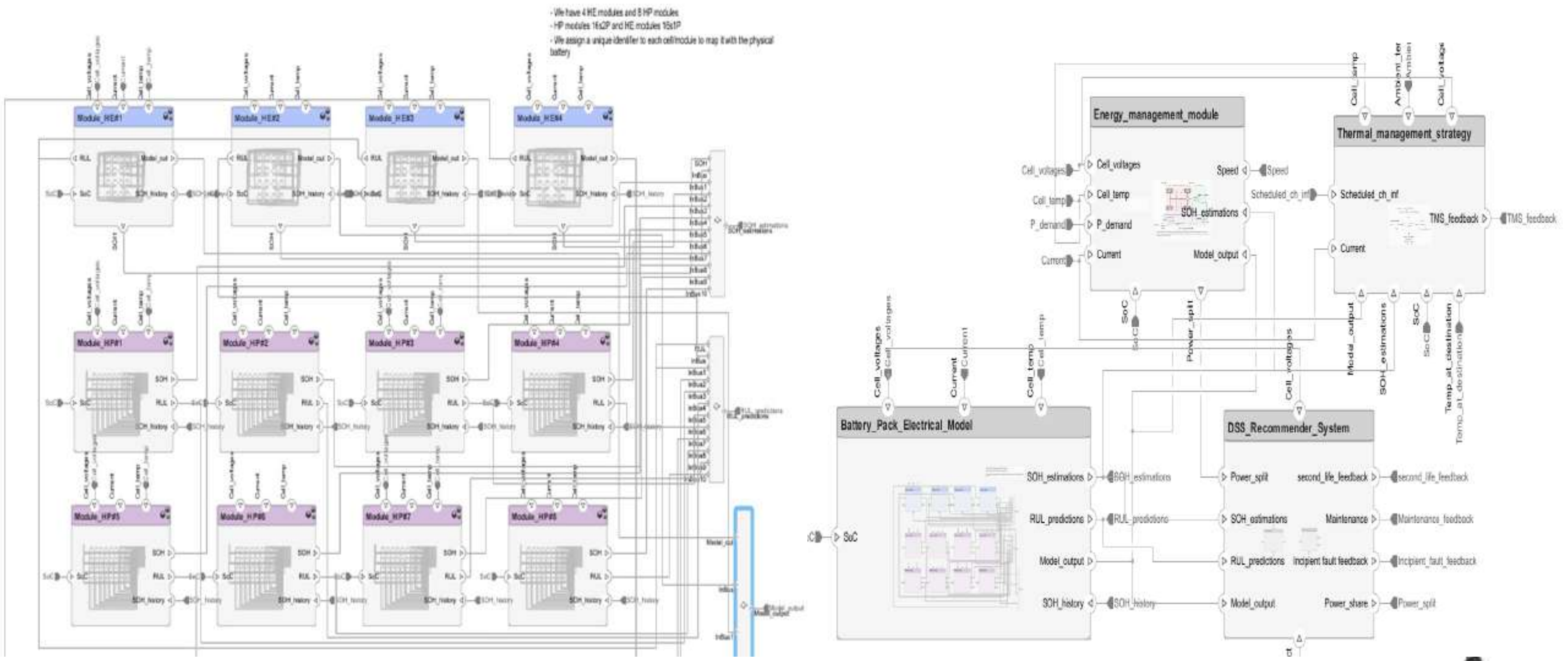
- *Integration of the different sub models and methods*

HELIOS Digital Twin approach

T4.5 Complete model for the development of the digital twin (AU)

Integrates all submodels (electric, thermal, thermal runaway and aging) and methods for state estimation, health management and RUL estimation into one complete digital twin mega-model operated on an IoT platform. It addresses the alignment and data exchange between different models and interface definition





Thank you for your kind attention

Towards a NEW GENERATION of EV battery packs for GREEN MOBILITY

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