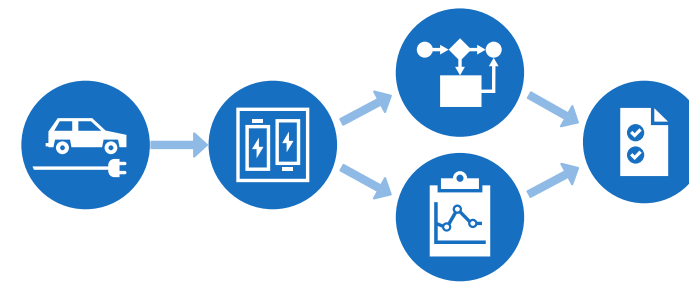# Systematic Battery State Estimation Algorithm Assessment – a Model-in-the-Loop Approach

35th International Electric Vehicle Symposium (EVS35)
Oslo, Norway

13.06.2022
Dominik Jöst
Katharina Quade, Franziska Berger, Dirk Uwe Sauer

Chair for Electrochemical Energy Conversion and Storage Systems
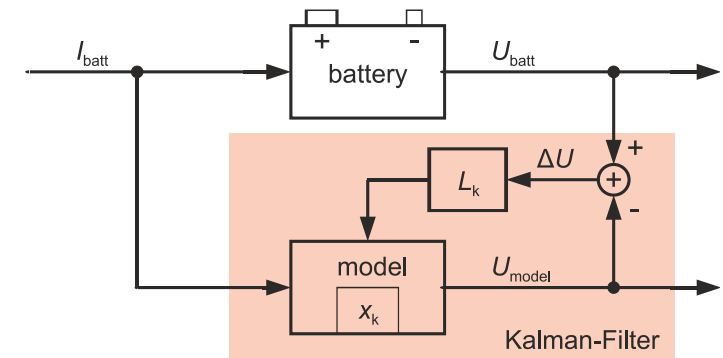
Lithium-Ion Battery Management

BMS Hardware
Measure and Compute

Goal 1
Safety

Goal 2
Optimized Battery Use

Lithium-Ion Battery Safety Window

Kalman-Filter

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems
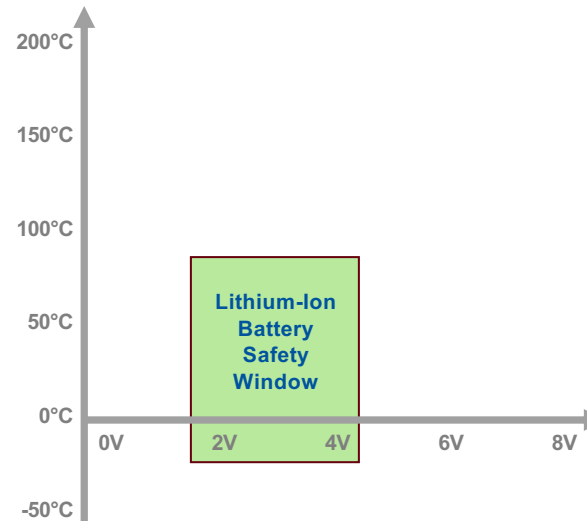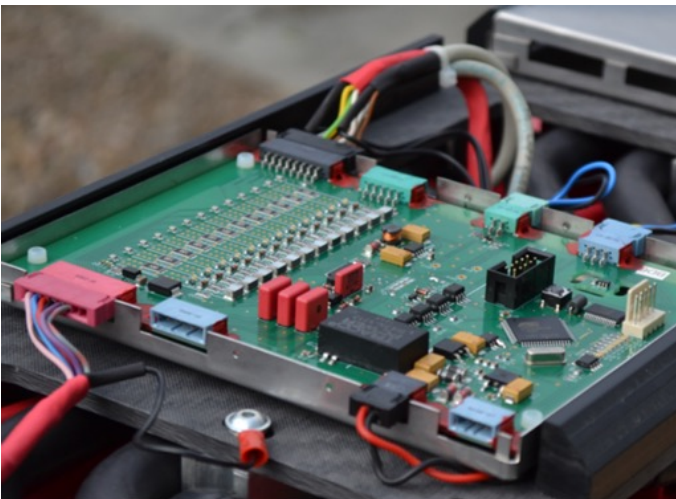
Applications for Lithium-Ion Batteries
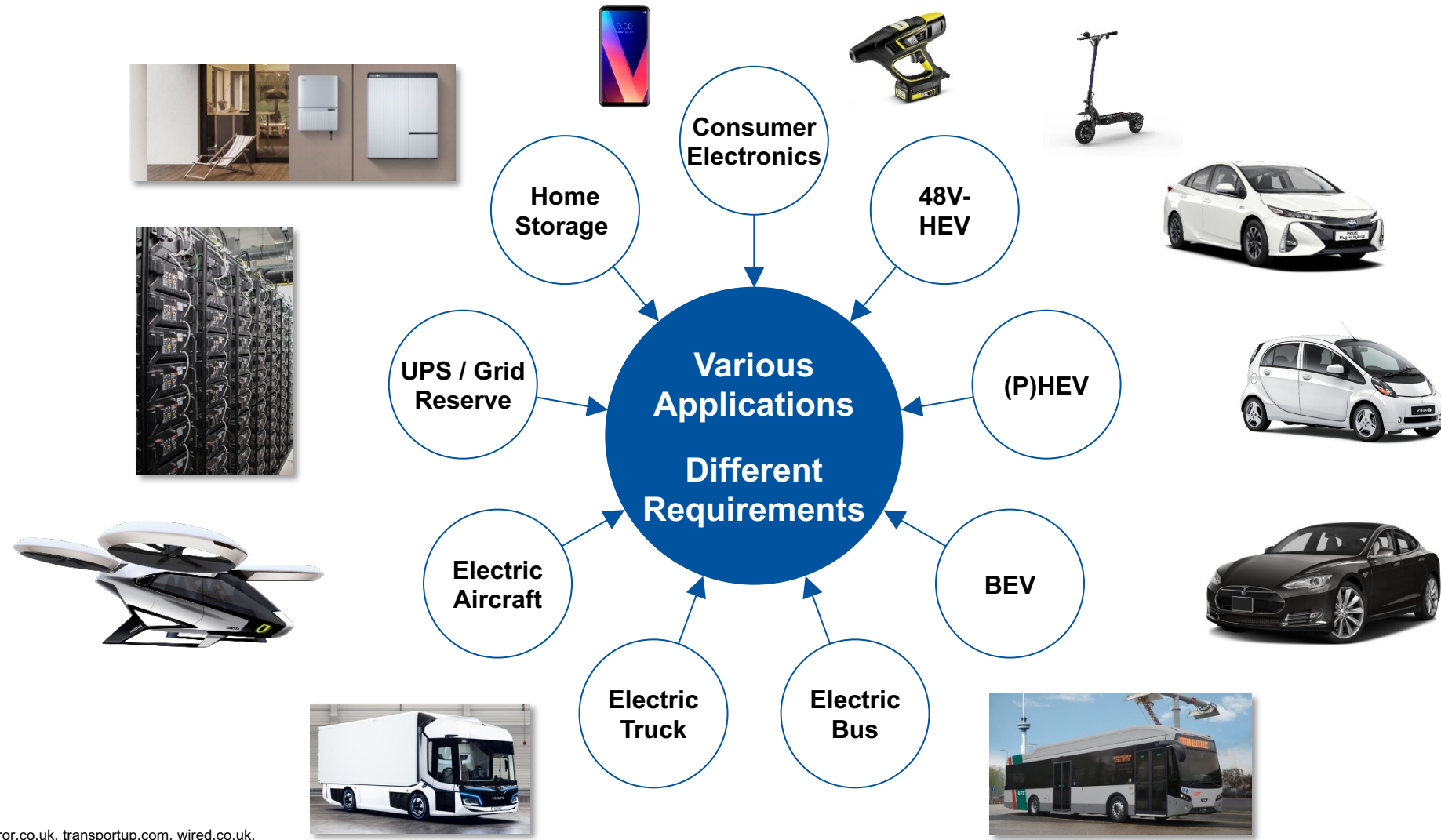
Various Applications

Different Requirements

- Home Storage
- Consumer Electronics
- 48V-HEV
- UPS / Grid Reserve
- (P)HEV
- Electric Aircraft
- BEV
- Electric Truck
- Electric Bus

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
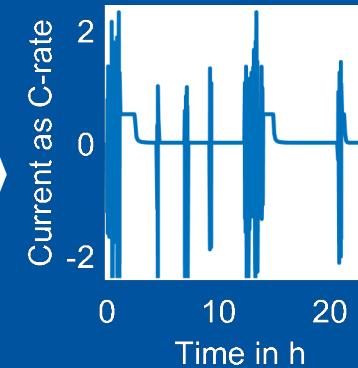Chair for Electrochemical Energy Conversion and Storage Systems

Application Characteristics - Example

Small BEV

16 kWh
88 Cells
-20°C – 50°C

Source: zigwheels.my
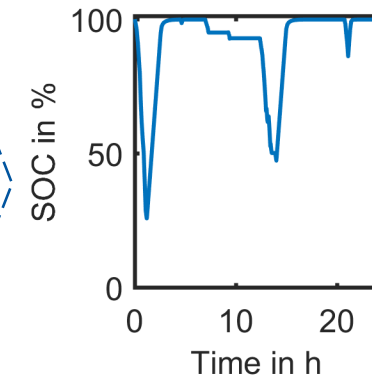
Primary Reserve

2.25 MWh
~10 000 Cells
~ 20°C

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems

Toolchain for Algorithm Assessment

Battery Management

Application

Battery System

Reference States

Evaluation

Application Model

Vehicle Database

Vehicle Model

Synthetic Profiles
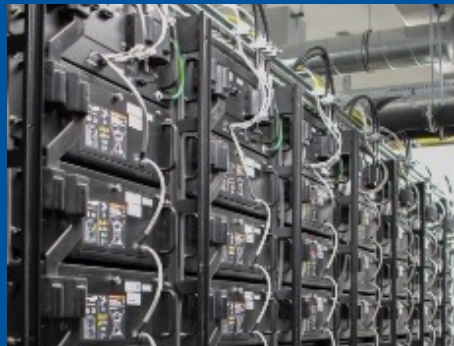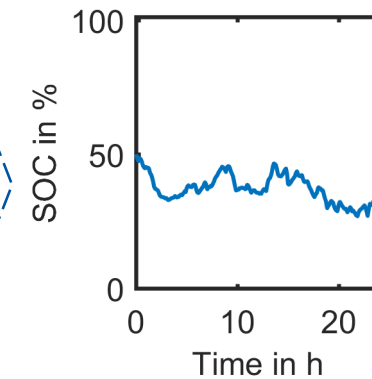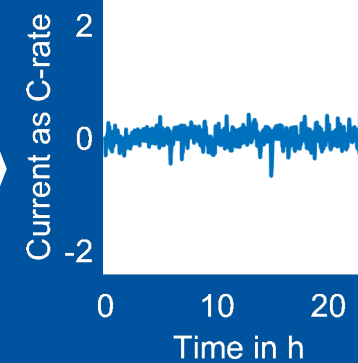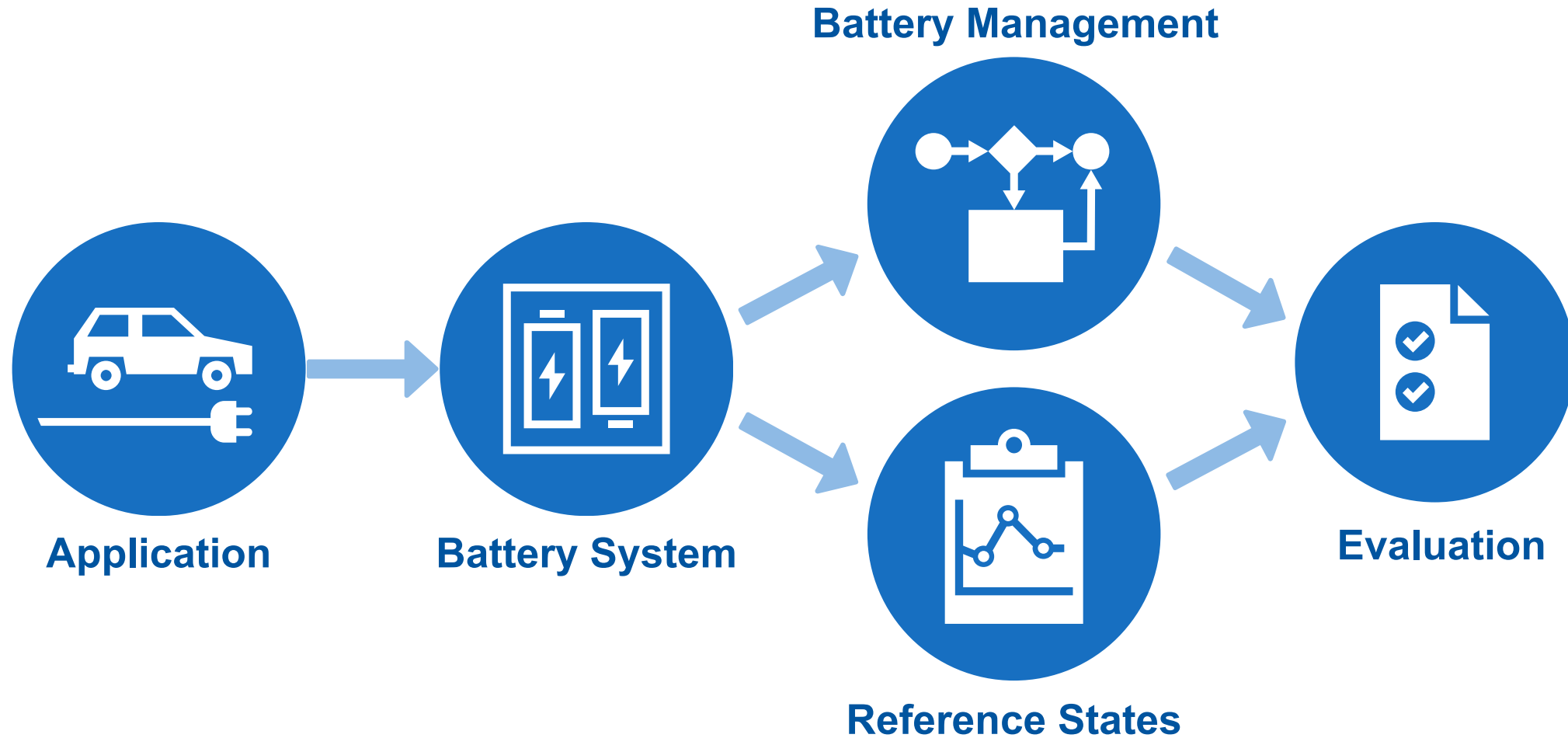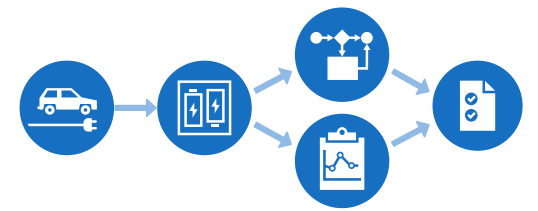
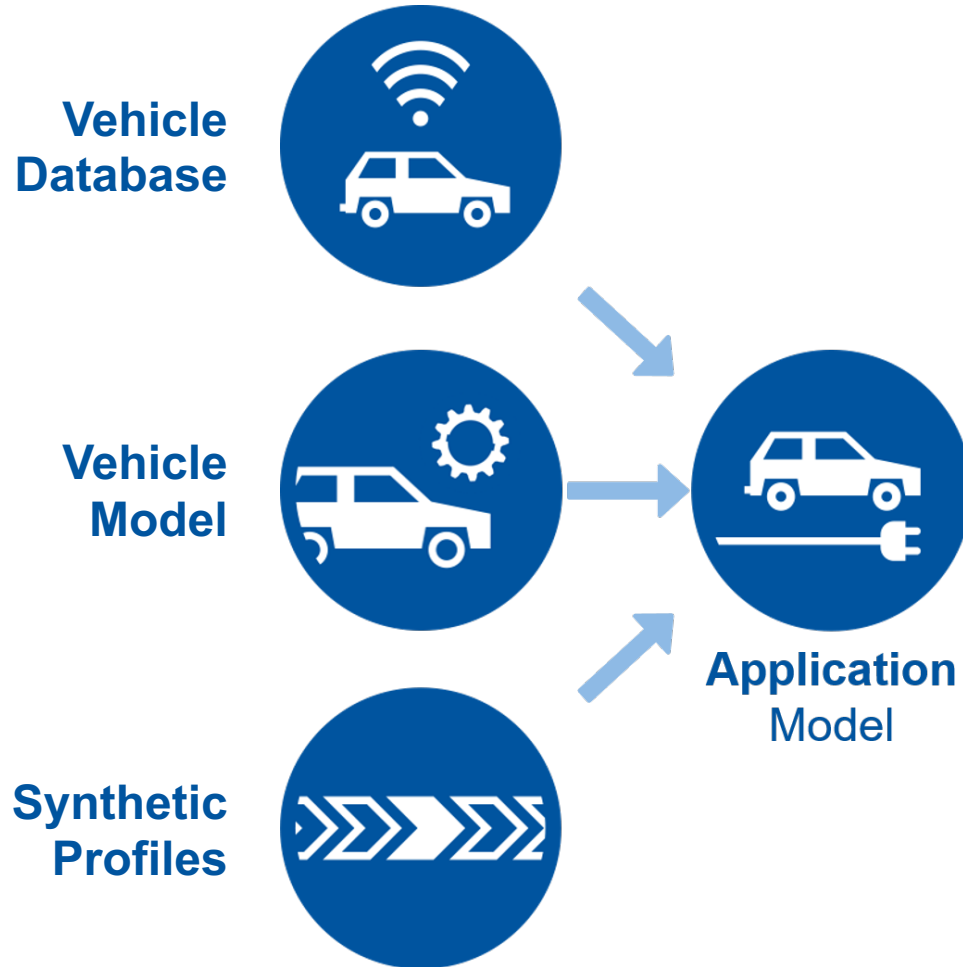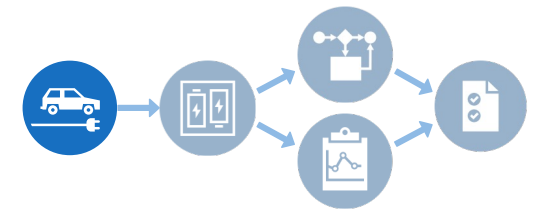**Application** Model

Database
- Trips of various ISEA cars logged and stored on a server
- Possibility to filter the trips by many options
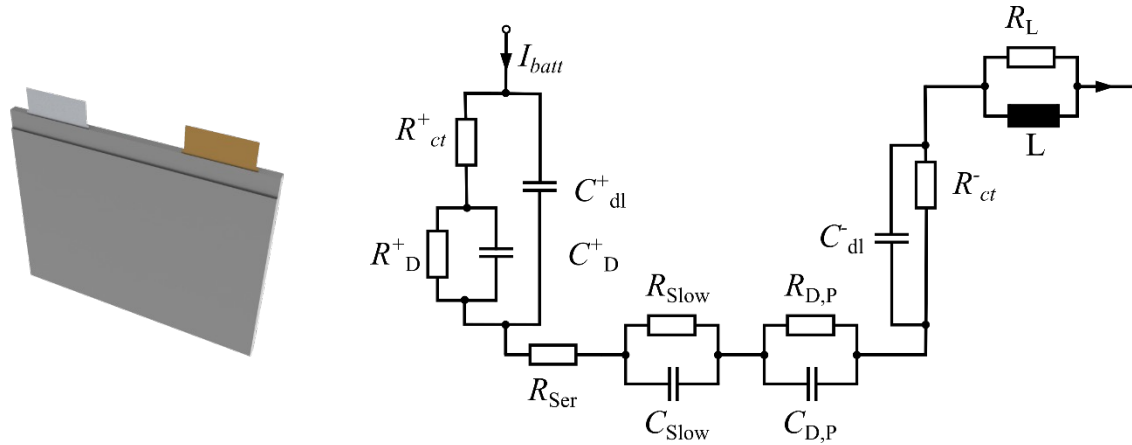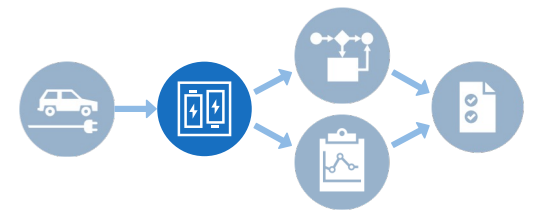- 24 Vehicles | >20,000 Trips | > 180,000 km | > 9,500 h

Model
- Power simulated from velocity profiles with different drivetrain topologies of electric and hybrid vehicles
- Many predefined standard velocity profiles
- Adaptable operating strategies and vehicle parameters

Synthetic
- Set of different synthetic profiles that can be scaled and repeated at different SOC levels
- Allows isolated investigation of specific effects

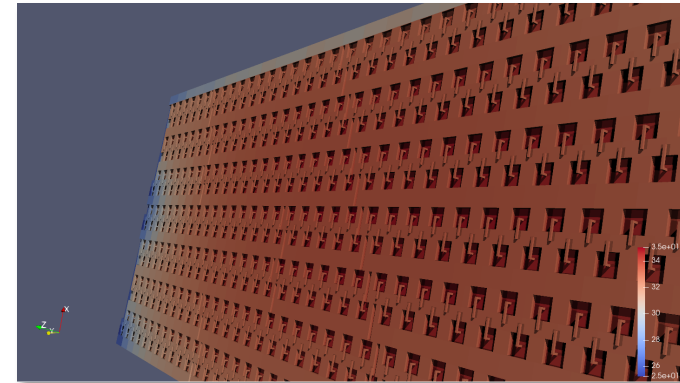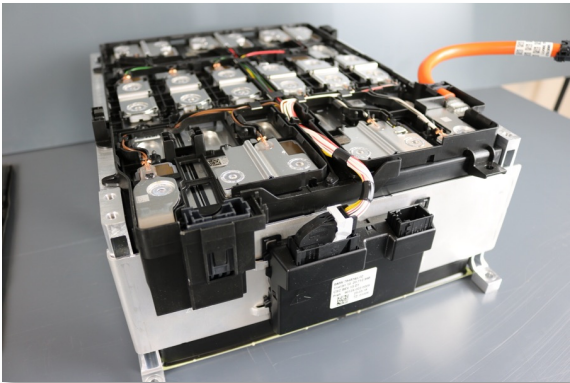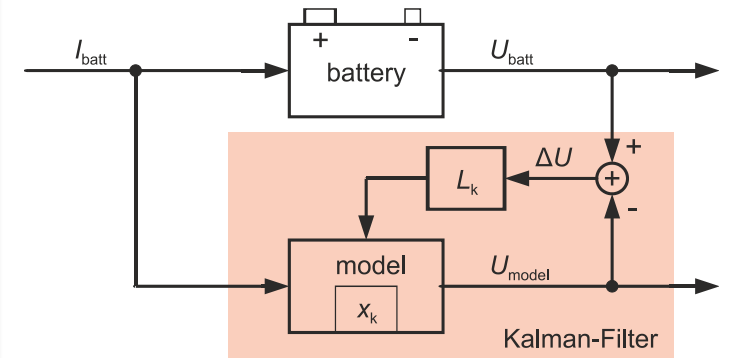13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems

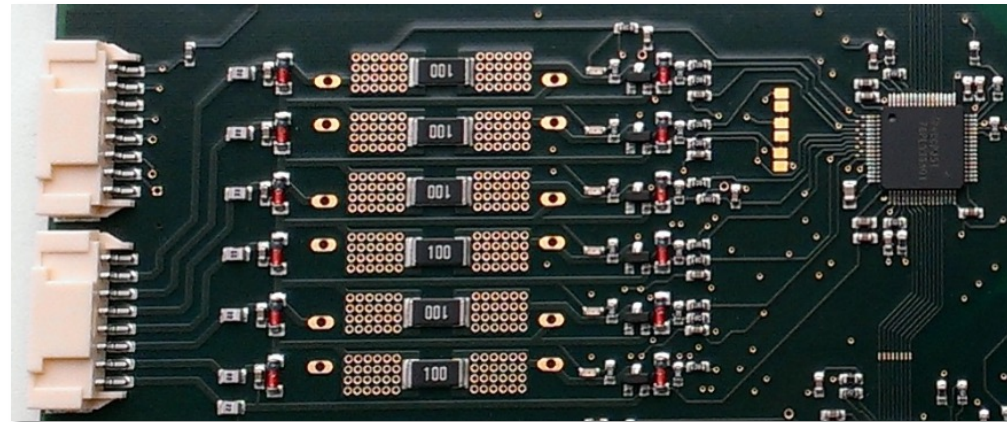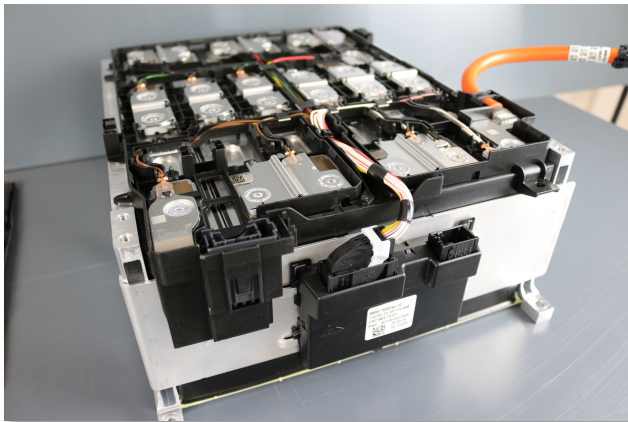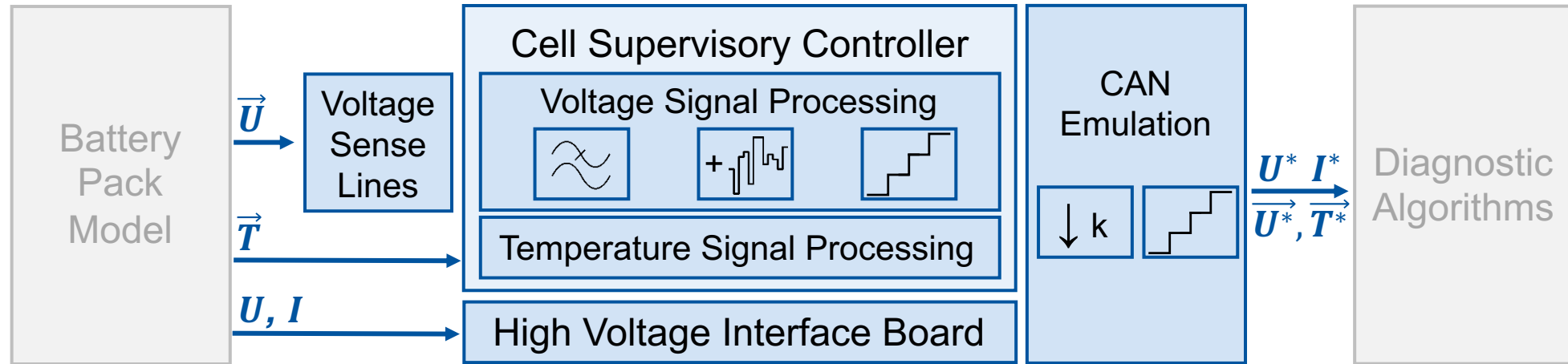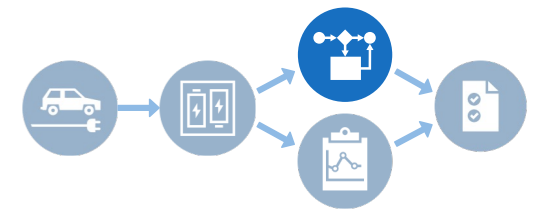# Battery System Model

■ Cell Model
  □ Physically motivated equivalent circuit model

■ Pack Model
  □ Wiring / connection resistances
  □ Parameter scattering, Ageing
  □ Losses, Heating, Cooling

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems

BMS Hardware Model

Modular Diagnostics Framework

Reference States and Evaluation
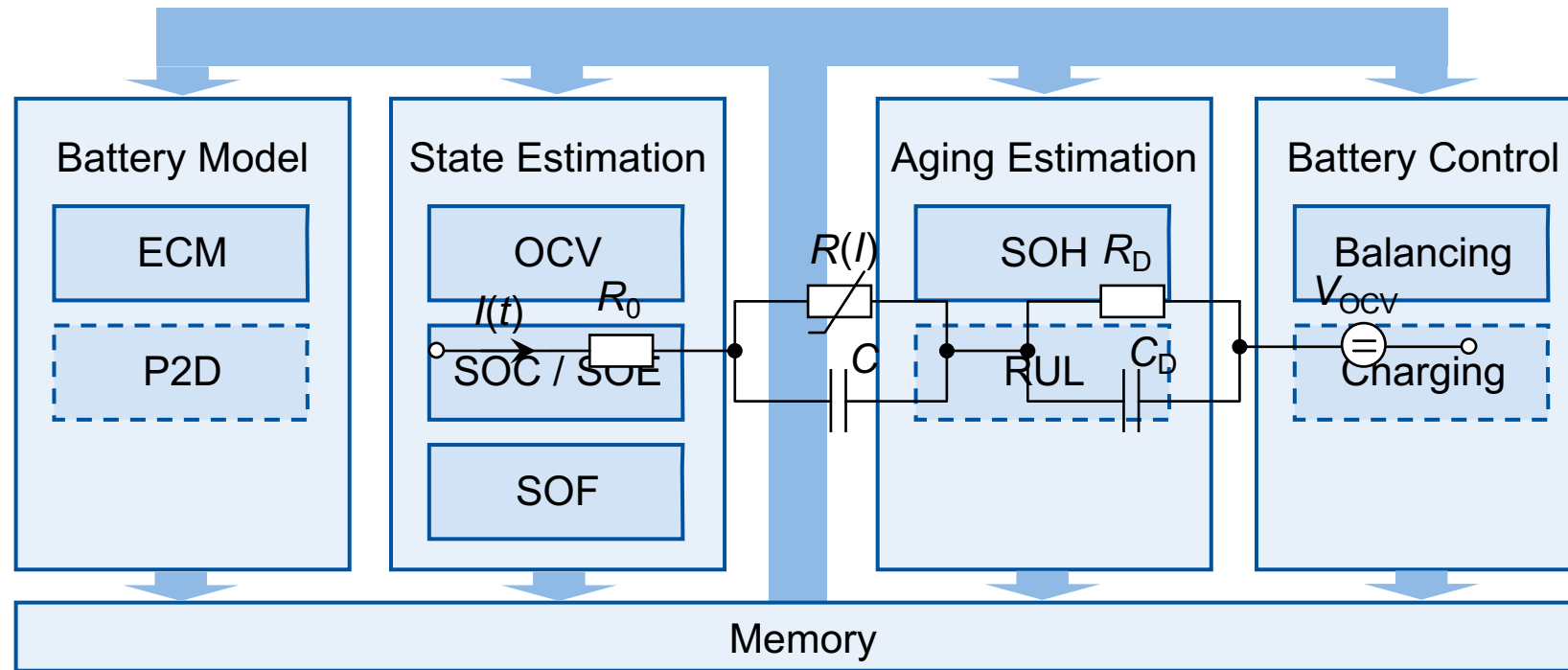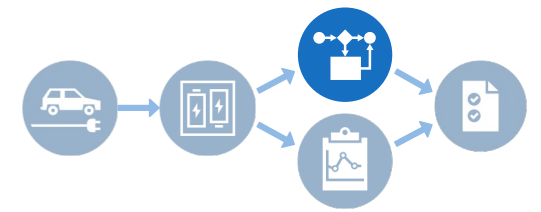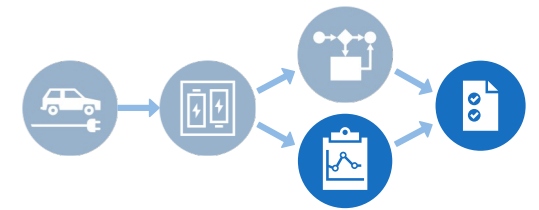
BMS Model

- Estimates battery states using diagnostic algorithms

- Takes into account hardware, noise etc.

- Shows interaction of the algorithms

Reference State Calculation

- Takes available states directly from reference model (SOC, $\underline{Z}$, C)

- Calculates battery states not directly available in reference model with full resolution (SOH, SOF)

Evaluation

- Compares estimated and reference states

- Multiple simulations for analysis of e.g.
  - Drift and transient behavior
  - Offset / noise / error stability

- Optionally generates visualizations
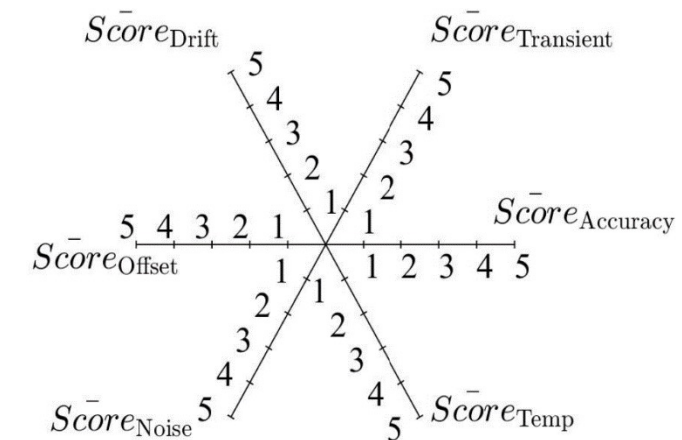
Example Results – Low Dynamic Scenario SOC Estimation

Input Profile (Low Dynamic)
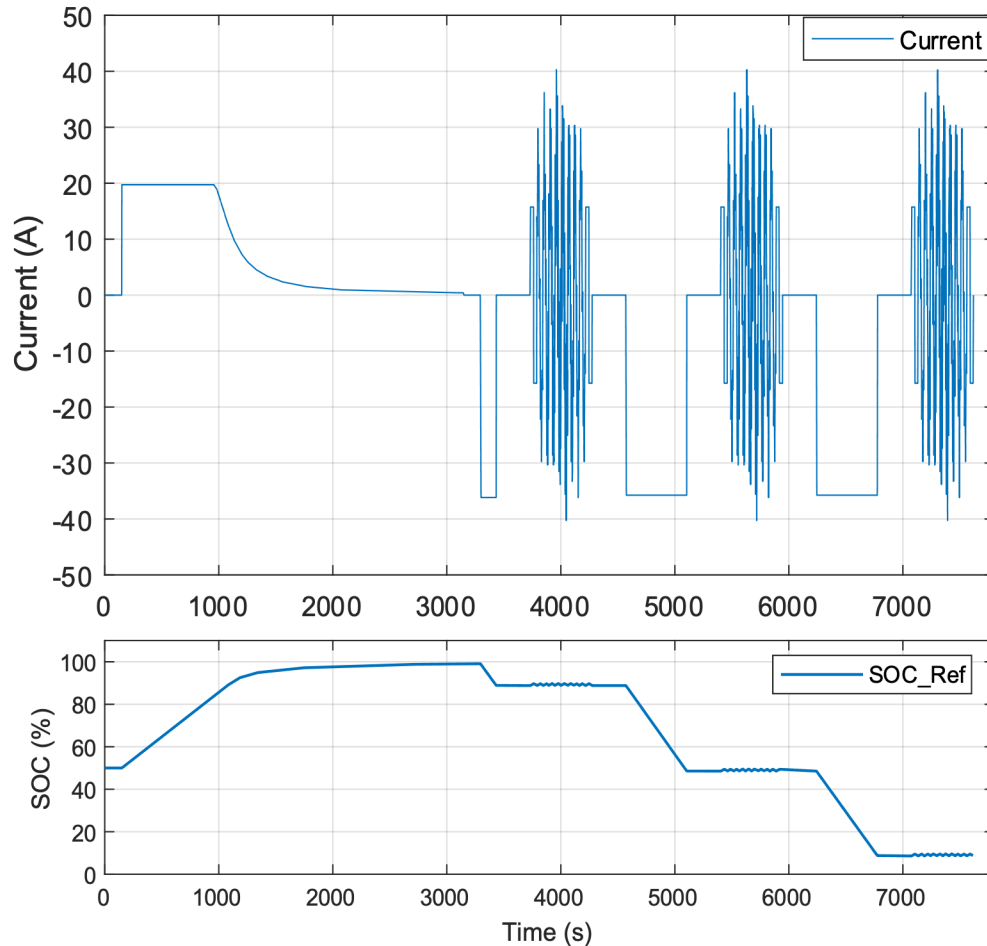
SOC Estimation Output
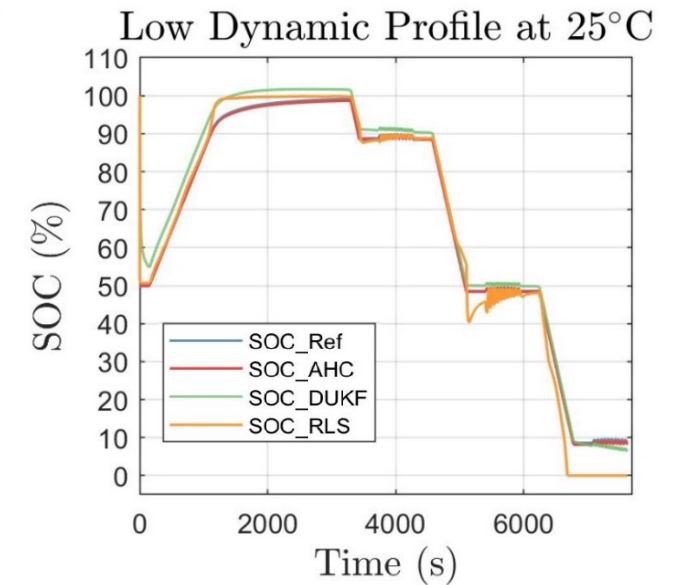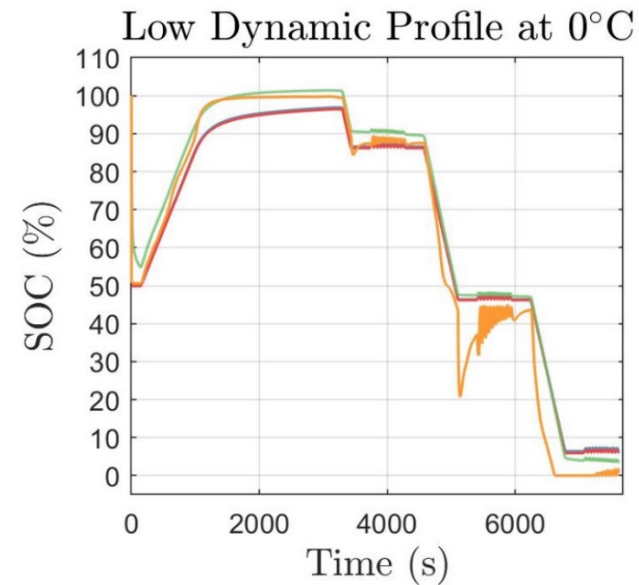
Example Results – Long Term Stability Scenario SOC Estimation

Input Profile (Long Term Stability)
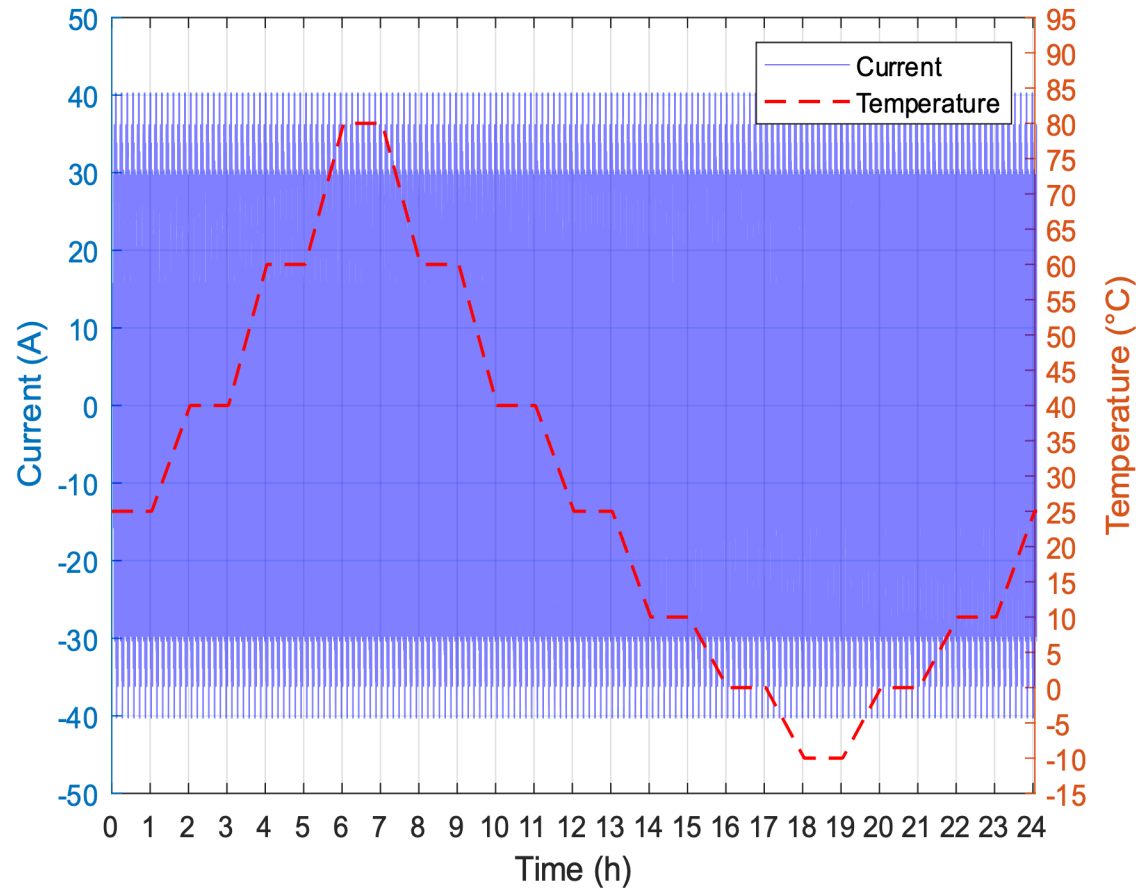
SOC Estimation Output

No Noise/Offset
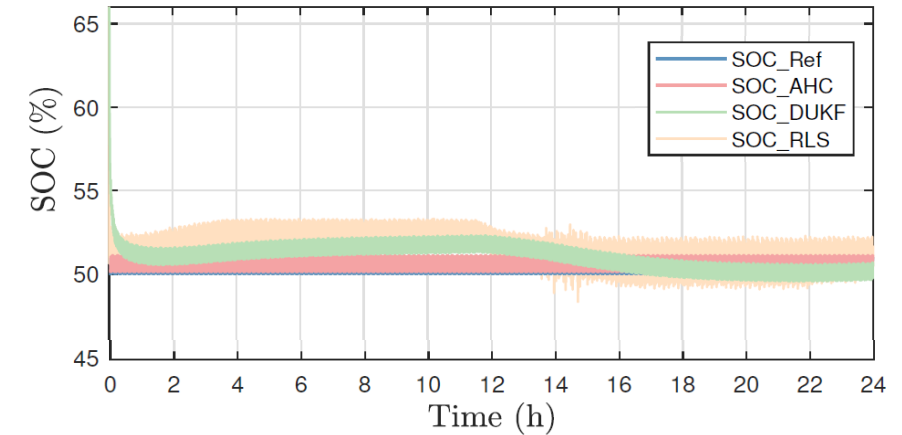
0.5% Current Sensor Offset

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems
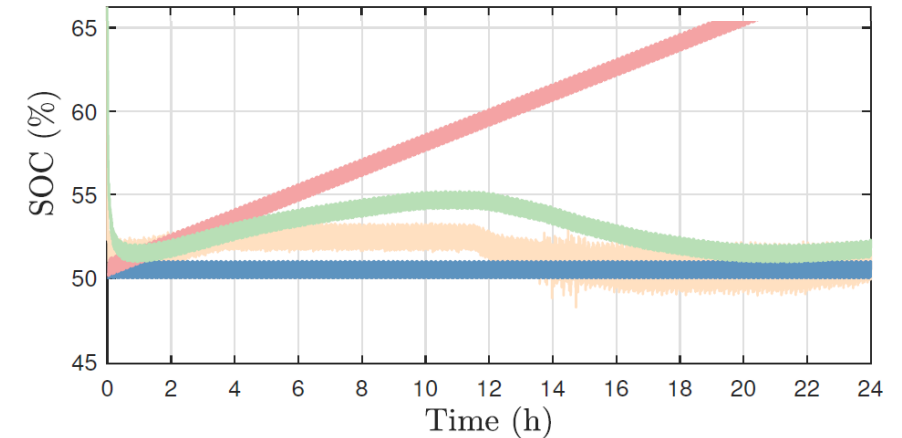
Example Results – SOC Benchmark Scores

■ Investigated behavior of 3 different SOC estimation approaches

■ Analyzed 224 simulations with synthetic profiles for this work (4 shown)

Low Dynamic Profile	Long Term Stability Profile

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems

Conclusion and Outlook

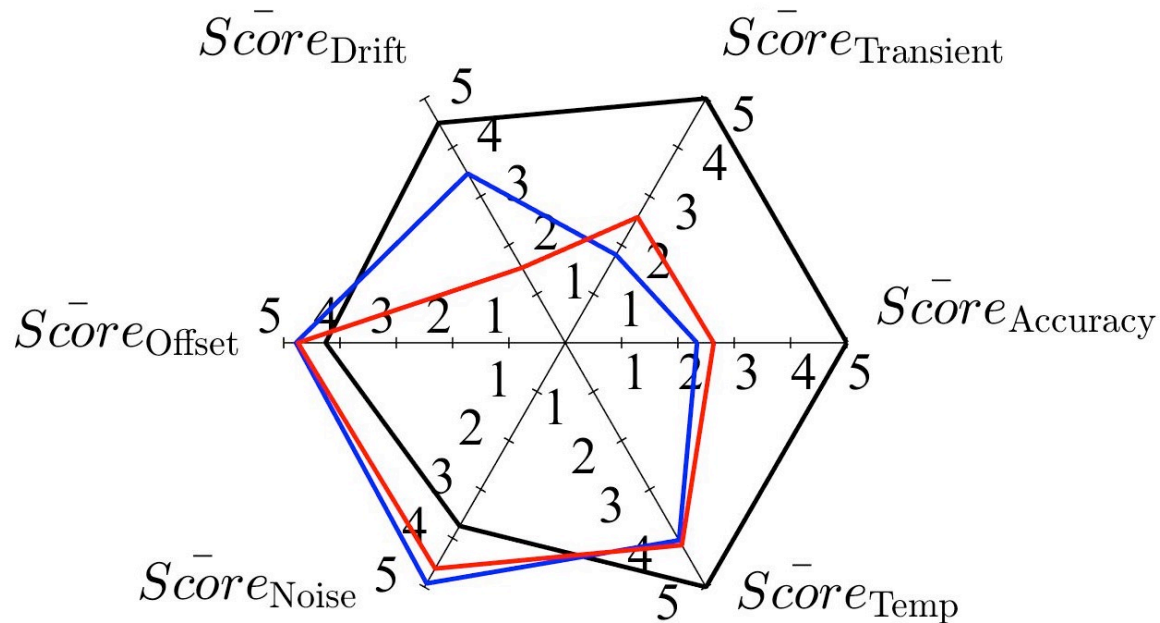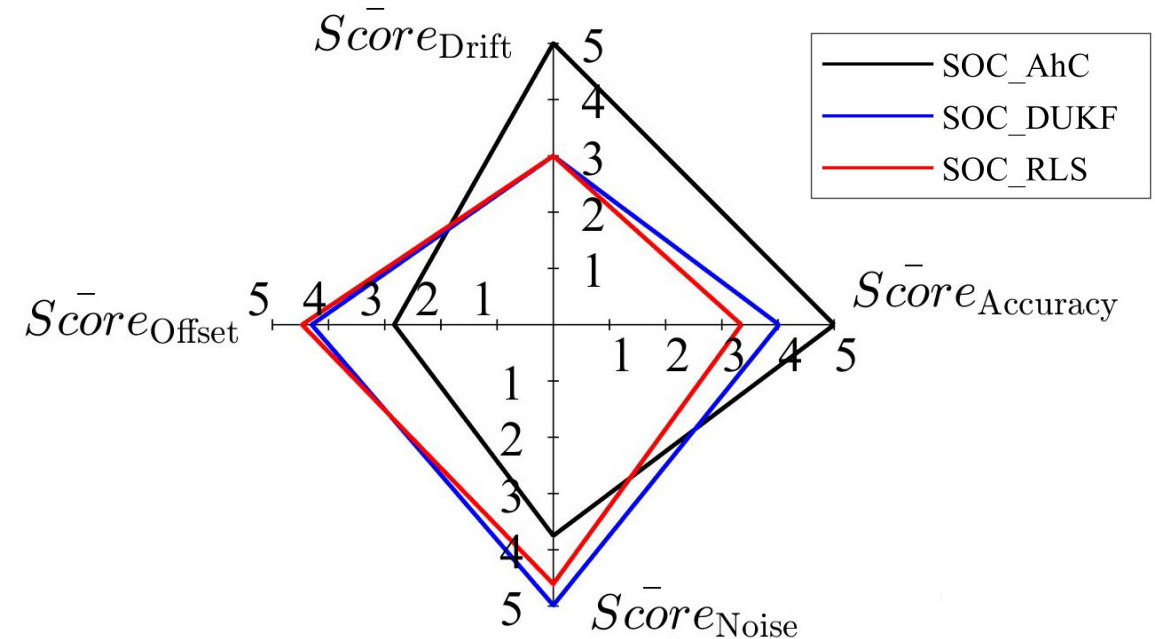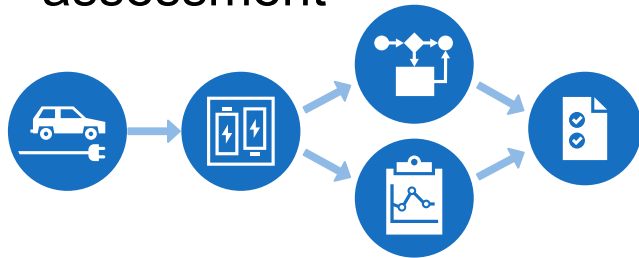| Toolchain	Possibilities	Future Work

■ Model-based toolchain developed
 	
■ Signal path from source to algorithm
 	
■ Evaluation of algorithm performance
 	
■ Multiple simulations for a comprehensive assessment
	■ Adapt to
	  ■ Application
	  ■ Battery system
	  ■ BMS hardware
	
	■ Compare algorithm implementations
	
	■ Select algorithms for a application
	
	■ Evaluate algorithm interaction
		■ Analyze different diagnostic algorithms
		
		■ Analyze further Li-Ion Chemistries
		
		■ Improve toolchain
		  ■ Individual weighting of operation points
		  ■ Assess computing power
		  ■ Automation of algorithm selection

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems

Batteries and Power Electronics at RWTH Aachen ISEA

Source: wikipedia.org

13.06.2022 | Dominik Jöst, Katharina Quade, Franziska Berger, Dirk Uwe Sauer
Chair for Electrochemical Energy Conversion and Storage Systems

Thank you
for your attention

Contact

Dominik Jöst
Tel.: +49 241 80-49396
djoest@isea.rwth-aachen.de
batteries@isea.rwth-aachen.de

Chair for Electrochemical Energy Conversion
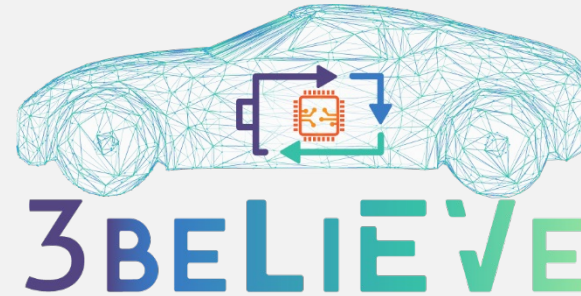and Storage Systems
Univ.-Prof. Dr. rer. nat. Dirk Uwe Sauer
RWTH Aachen University

Jaegerstrasse 17/19
52066 Aachen
GERMANY

www.isea.rwth-aachen.de

We thank

3BELIEVE

GA 875033

DUETT
2014
20

Hybridfahrzeuge in physischer und virtueller Umgebung

EFRE.NRW
Investitionen in Wachstum
und Beschäftigung

EUROPEAN UNION
Investing in our Future
European Regional
Development Fund

ERDF-0800841

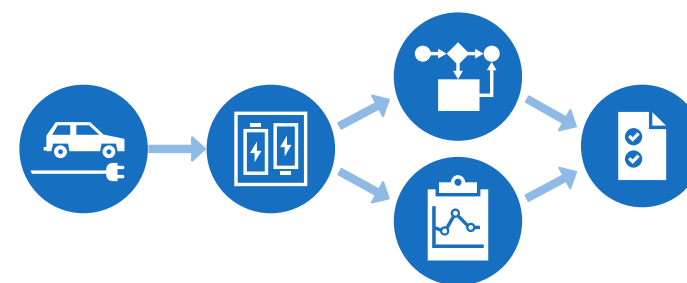ISEA Power Electronics and Electrical Drives | RWTH AACHEN UNIVERSITY

Systematic Battery State Estimation Algorithm Assessment – a Model-in-the-Loop Approach

35th International Electric Vehicle Symposium (EVS35)
Oslo, Norway

13.06.2022
Dominik Jöst
Katharina Quade, Franziska Berger, Dirk Uwe Sauer

Chair for Electrochemical Energy Conversion and Storage Systems