ALBATROSS BATTERY MANAGEMENTS SYSTEMS

COLLABAT Workshop
26.11.2024

Ceren Acar – FEV TR

Agenda

- Albatross Introduction
- EIS Circuit Example Results
- Hybrid Dual Kalman & AI SOC Calculation
- Anode Control Charge Algorithm
- LSTM Based SOH Algorithm
- Cloud Architecture
- Summary of Albatross Outputs
- Demonstration

ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

FEV Resposibilities

Brief Information

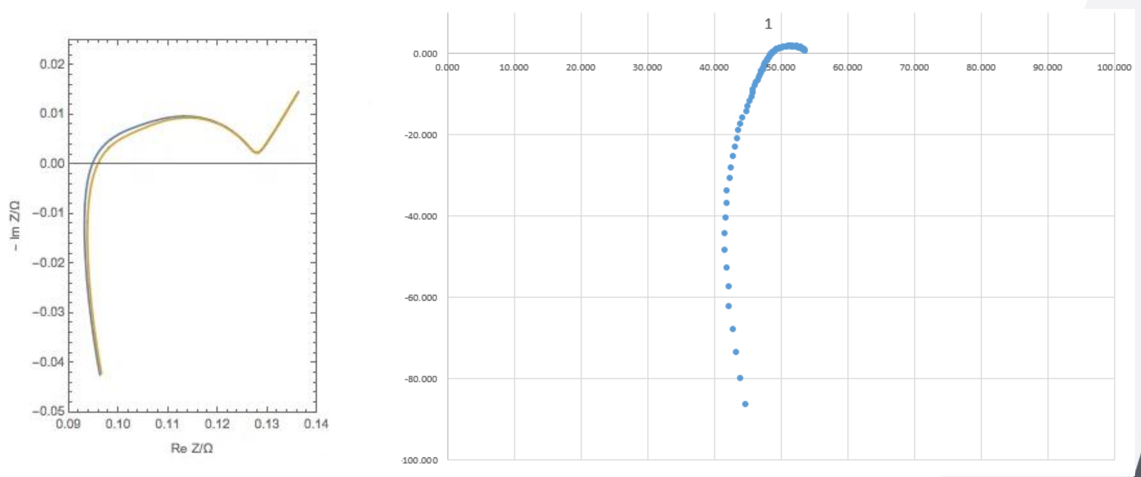
- To create flexible advanced battery management systems (BMS) capable of being used on different types of packs and mid-sized vehicles with different use patterns
- Key outcomes of the projects for FEV:
    - High Voltage BMS Hardware up to 800 V
    - System-on-Chip based Battery Master Unit
    - Novel AI based SoX Algorithms
        - AI Based State of Health **(SOH)** calculations on Cloud
        - Anode Controlled Charge **(ACC)** algorithm
        - Kalman-filtered State of Charge **(SOC)** algorithm
    - Cloud connected BMS & Monitoring services

ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

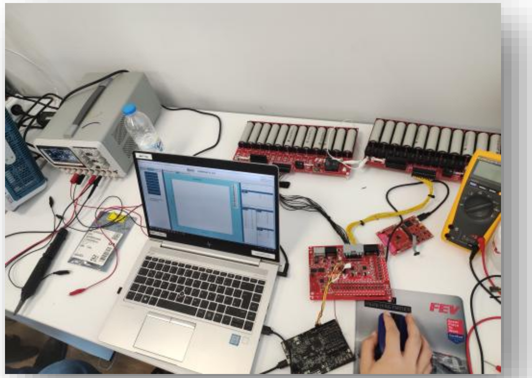
EIS Circuit Example Results

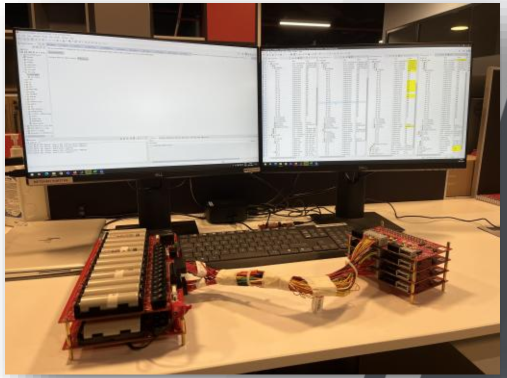
Brief Information

- Normal EIS devices can only measure one cell.
- However, CMU will be able to measure 24 series connected cells.
- CMU uses a special switch technique to connect all 24 cells to measurement circuit.
- These concept was verified on real hardware and received promising results. As further studies, the concept needs to be developed.



Theoretical vs measured EIS results





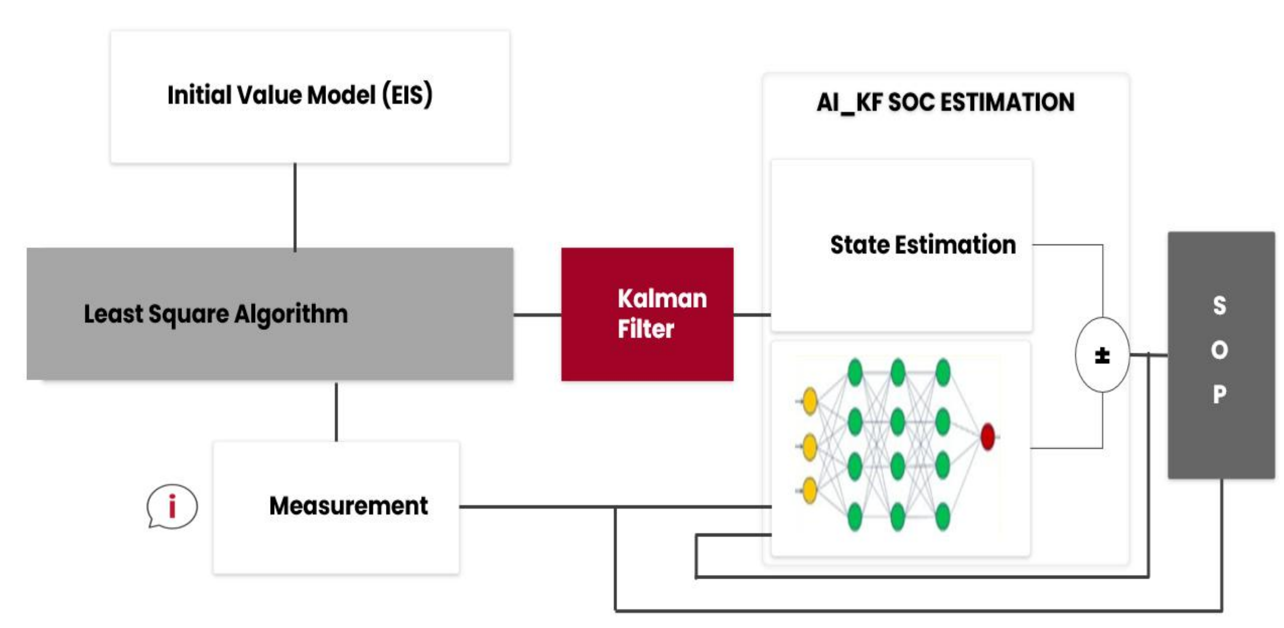
ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

Hybrid Dual Kalman&AI SOC Calculation

Hybrid algortihm goal is to minimize measurement errors, on top of that EIS real data will feed into this algortihm.

- Battery Parameter Esitmation
  EIS & Least square based approach has been developed
- Capacity Estimation
  Model based adaptive extended kalman filter has been adopted
- SOC Calculation
  LSTM & model based approach has been developed

Based on a precise and accurate SOC estimation, the BMS can optimize energy efficiency and protect the battery from the dangers such as being over-charged or over-discharged.



ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

Anode Control Charge Algortihm

ACC algortihm goal is to reduce to charge time for end users.

- Battery Parameter Esitmation

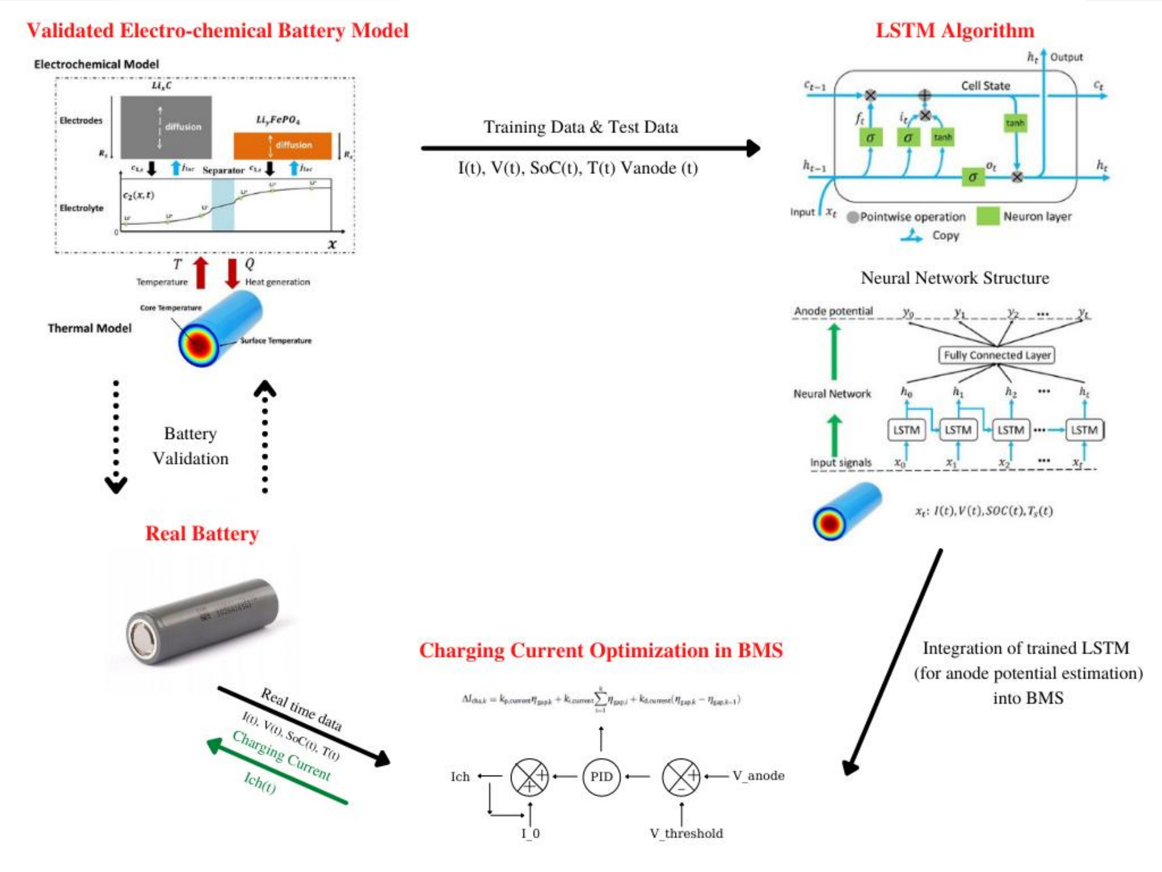
  Parameter data set is generated by physical model.

  Physical model is fed by WLTP vehicle data and laboratory cell data set.

- Anode Voltage Estimation

  LSTM model was trained with physical model data set, at different temperatures and C-rates.

Anode potential has been used in charge control algortihm to decrease charge time.



ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

Anode Control Charge Algortihm

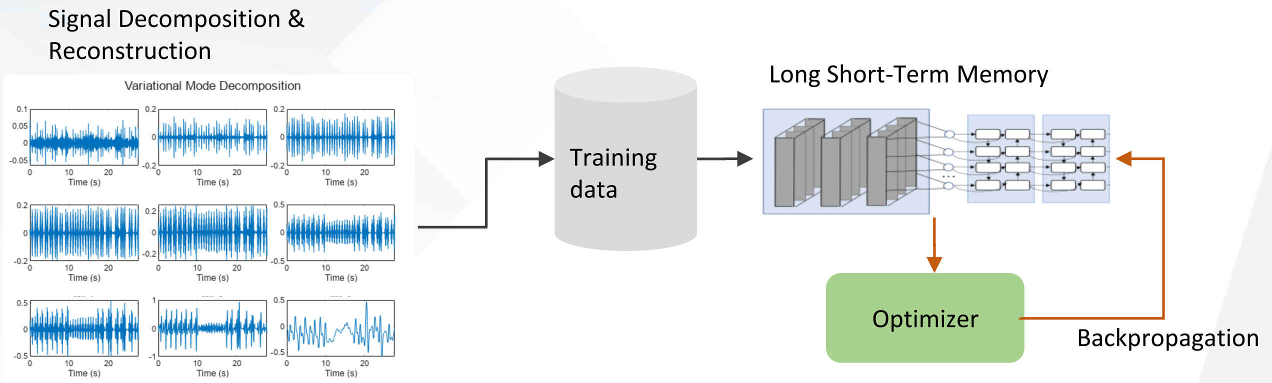
ACC algortihm goal is to reduce to charge time for end users.

- Charging data was obtained according to the CCCV method and LSTM was retrained by including the data in the training dataset.

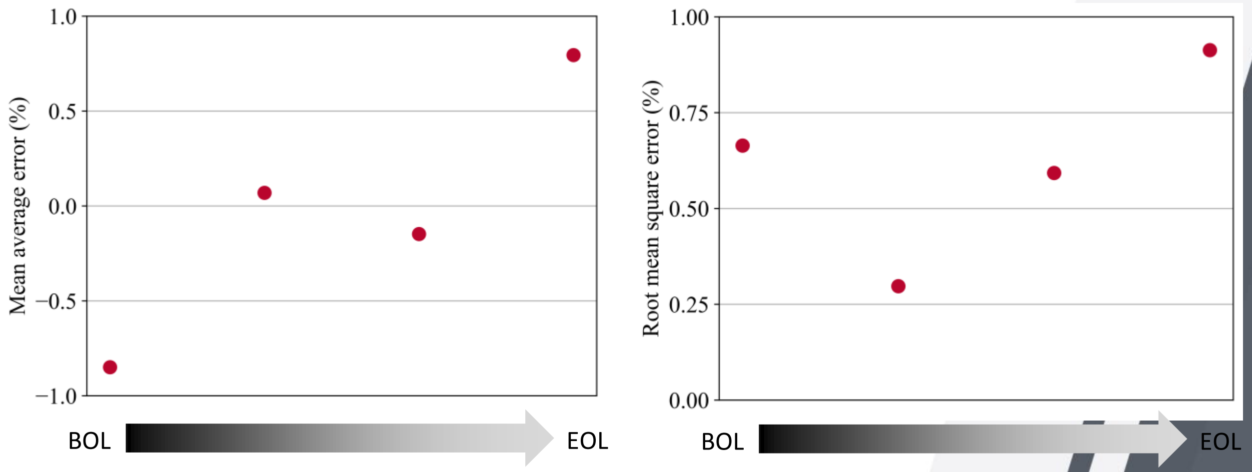
ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

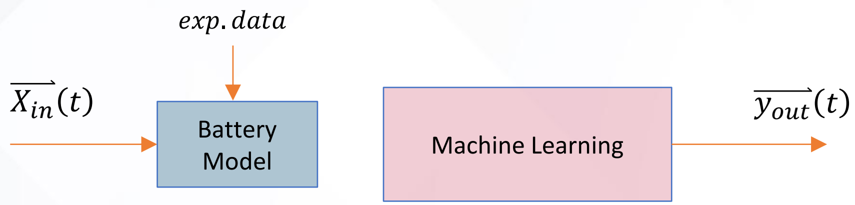
SOH estimation using Long-Short Term Memory Model

- SOH estimation based on LSTM
- Battery test bench data
  - Each between 400 and 700 ageing cycles
  - Capacity tests during ageing
  - 1 Hz sampling rate
  - NMC cells, also applied to LFP cells
- SOH accuracy of <1%
- Applicable to vehicle data using battery model

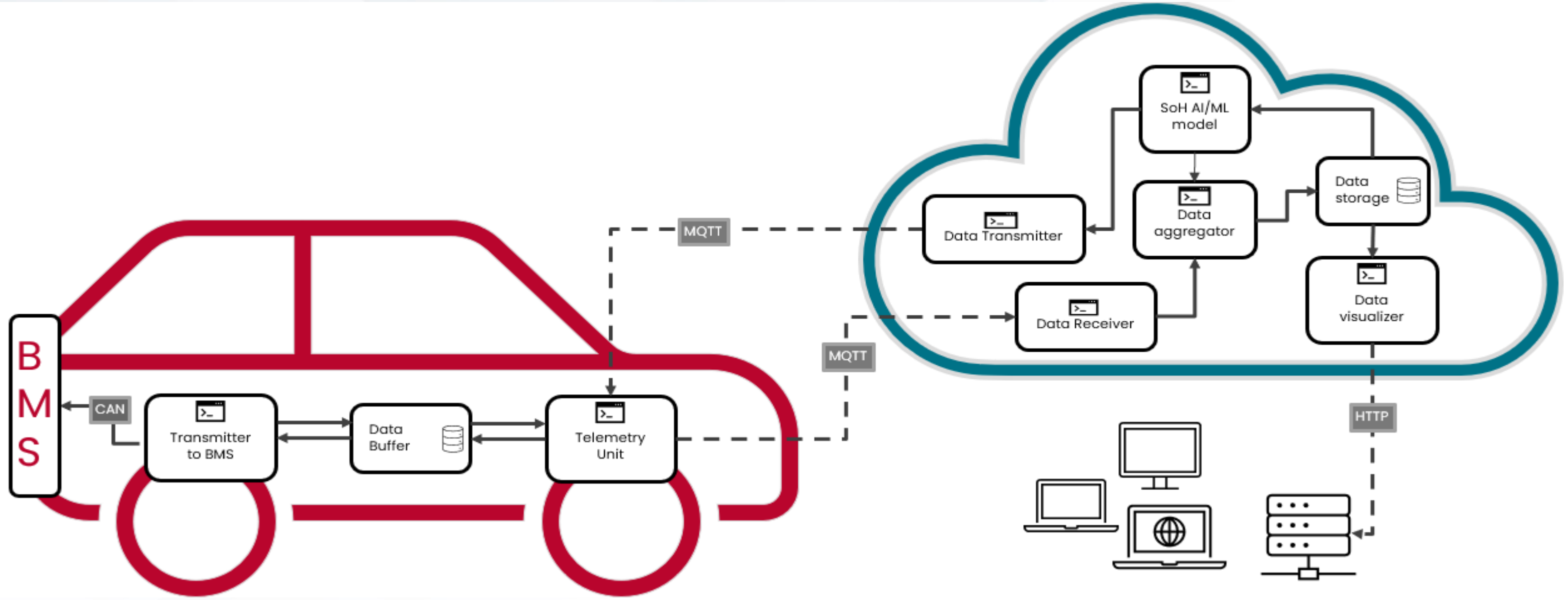


SOH evaluation





ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications



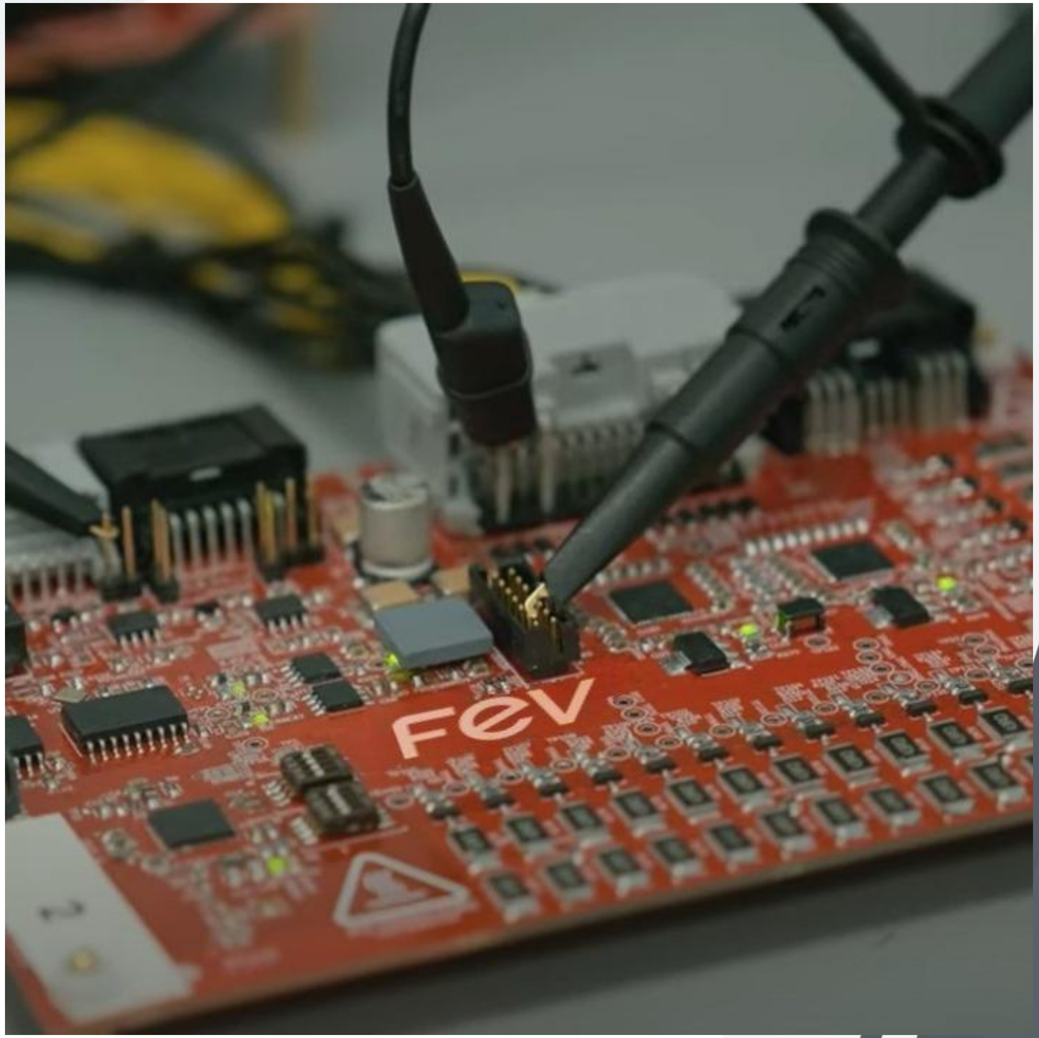
Cloud System Arhitecture

- Big data transmission and storage on the cloud
- Operates AI models of SOH algorithms
- Managing CAN & Cloud communication
- Data concentration & Network management
- Real time data monitoring

ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

Cell Monitor Unit

- Monitor and balance up to 24 cells
- State of the art 5. generation cell monitor AFE. On-board microcontroller, 1 CANBUS channel, 1 isoSPI channel
- Wireless connectivity (Wireless BMS Proof-of Concept) between master and slaves. WMCU-based concept
- On-board Electrochemical Impedance Spectroscopy (EIS) measurement
- 8 temperature measurement inputs
- Passive cell balancing (up to 800 mW per cell)
- Size optimized for compact pack modular design (150 mm x 100 mm x 20 mm)



ALBATROSS

ALBATROSS: Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications

Master Control Unit

- Texas Instrument System-on-Chip Based Design with 11 cores microprocessor & 1 GPU
- Cloud connectivity for advanced algorithms and data analytics
- Wireless communication link for enabling Wireless BMS
- CANBUS/LINBUS/ISOSPI Interfaces
  - Pack current & voltage monitoring
  - Isolation & Interlock Monitoring
  - Contactor drivers up to 6 contactors
- Real Time Clock, NVM
- Various programmable I/O
- Diagnostic functions

Summery of Albatross Outputs

• Cloud Connected BMS

Master – slave topology architecture is used.

BMU collects data from individual cells via CMUs. Working in conjunction with

BMU provides a comprehensive view of battery performance, enabling precise control and optimization of the charge and discharge processes.

Wireless communication between BMU and CMUs.

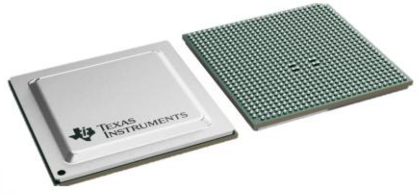
• System on Chip

Pioneering solution brings powerful processing ability.

Dedicated cores for various operations

Texas Instruments’ System on Chip solution was selected.

The solution has been fully integrated to BMU.



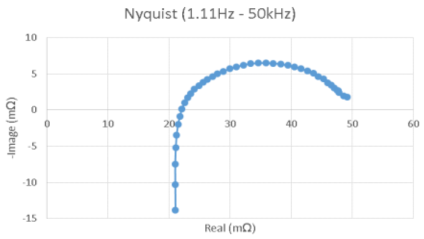
• EIS

Electrochemical Impedance Spectroscopy

Powerful technique that is used to analyze the electrochemical properties of batteries.

To apply EIS on board, specialized hardware is integrated into the BMS.

The response of the battery cells is measured at different frequencies.



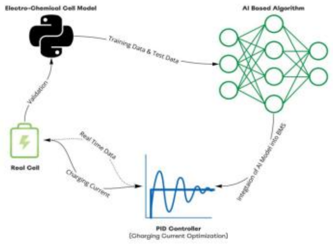
• Cutting Edge Algorithms

Concepts were generated models were developed. SW integration is ongoing.

SOC: A hybrid system uses both LSTM and UKF method for SOC estimation.

ACC: To reduce charging time (higher currents) by controlling anode potential.

SOH: ML algorithm is trained with data from accelerated aging test.



• Cloud Architecture

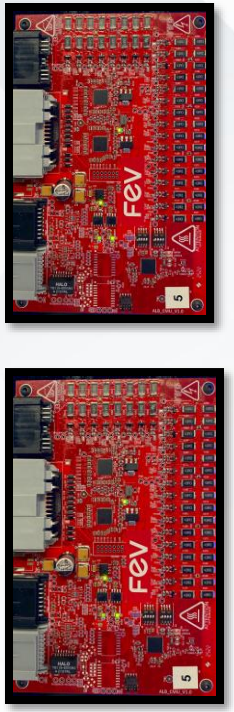
The concept covers information exchange between BMS and Cloud.

Big data transmission and storage on cloud

Train AI models of SOH algorithms

Results

Wire Connection



Wireless

Wireless

CAN Line

5 Cloud

The cloud system operates data monitoring & AI based advanced algorithms.

1 Battery Cell Stack

The battery, modules or cells that are measured and controlled by ALBATROSS BMS.

2 Cell Monitoring Units

The Cell Monitor Units measure real time data and send data via wireless communication.

3 Battery Master Unit

The Battery Master Unit processes data and generates various output using advanced algorithms.

4 Intelligent Connection Unit

The Intelligent Connection Unit receives data via CAN line, data is being processed and transferred to Cloud via internet.

SEI Automotive
Europe
FEV
We drive innovation to help the world evolve.
FEV propulsion
Battery Management System Solutions
ALBATROSS - Advanced Light-weight Battery systems Optimized for fast charging, Safety, and Second-life applications
ALBATROSS
Battery Cell Stack
Discharge
Charge
Cell Monitoring Units
Battery Master Unit
Intelligent Connection Unit

Your Contact

Efe Afacan
Team Leader

FEV Türkiye
E.Powertrain & Batt. Mech. Development

afacan@fev.com

Ceren Acar
Department Manager

FEV Türkiye
Battery Systems

acar@fev.com

THANKS!

WIRELESS BMS BY HELIOS

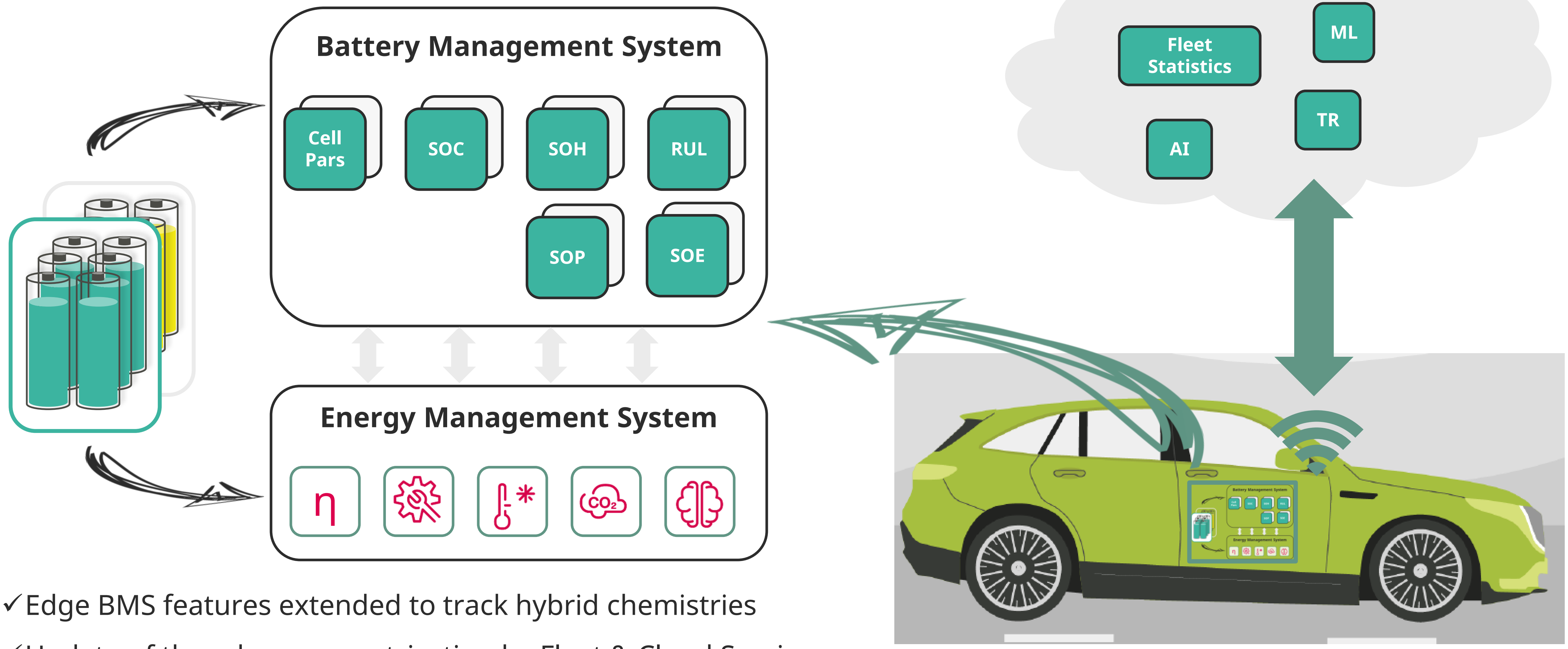
Alberto Romero - Schaeffler

November 2024

HELIOS

This project has been co-funded by the European Union's Horizon 2020 research and innovation programme under grant agreement no 963646. This document reflects the view of its author(s) only. Neither the European Commission nor the funding agency are responsible for any use that may be made of the information it contains.

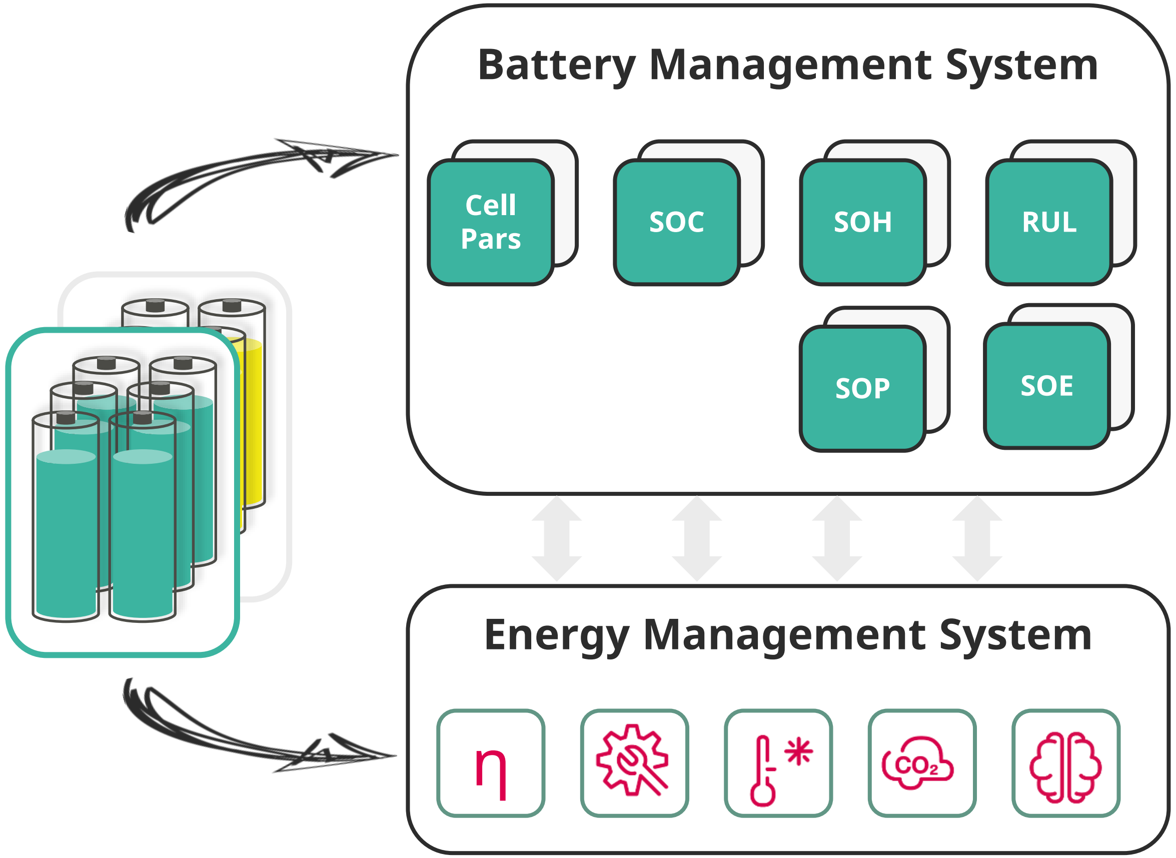
WIRELESS BMS by HELIOS



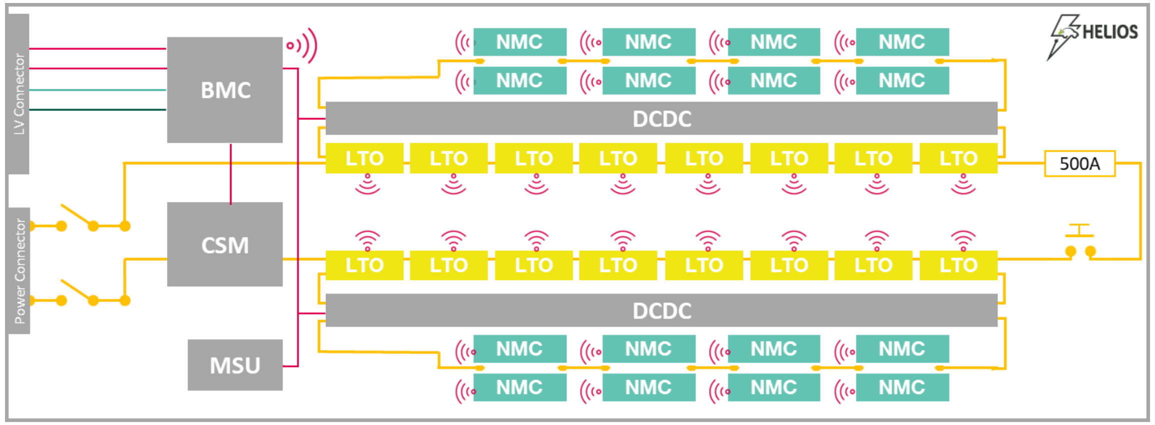
- ✓Edge BMS features extended to track hybrid chemistries
- ✓Update of the edge parametrization by Fleet & Cloud Services

Edge Battery Pack

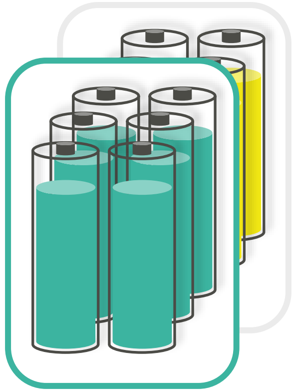
HELIOS SCHAEFFLER

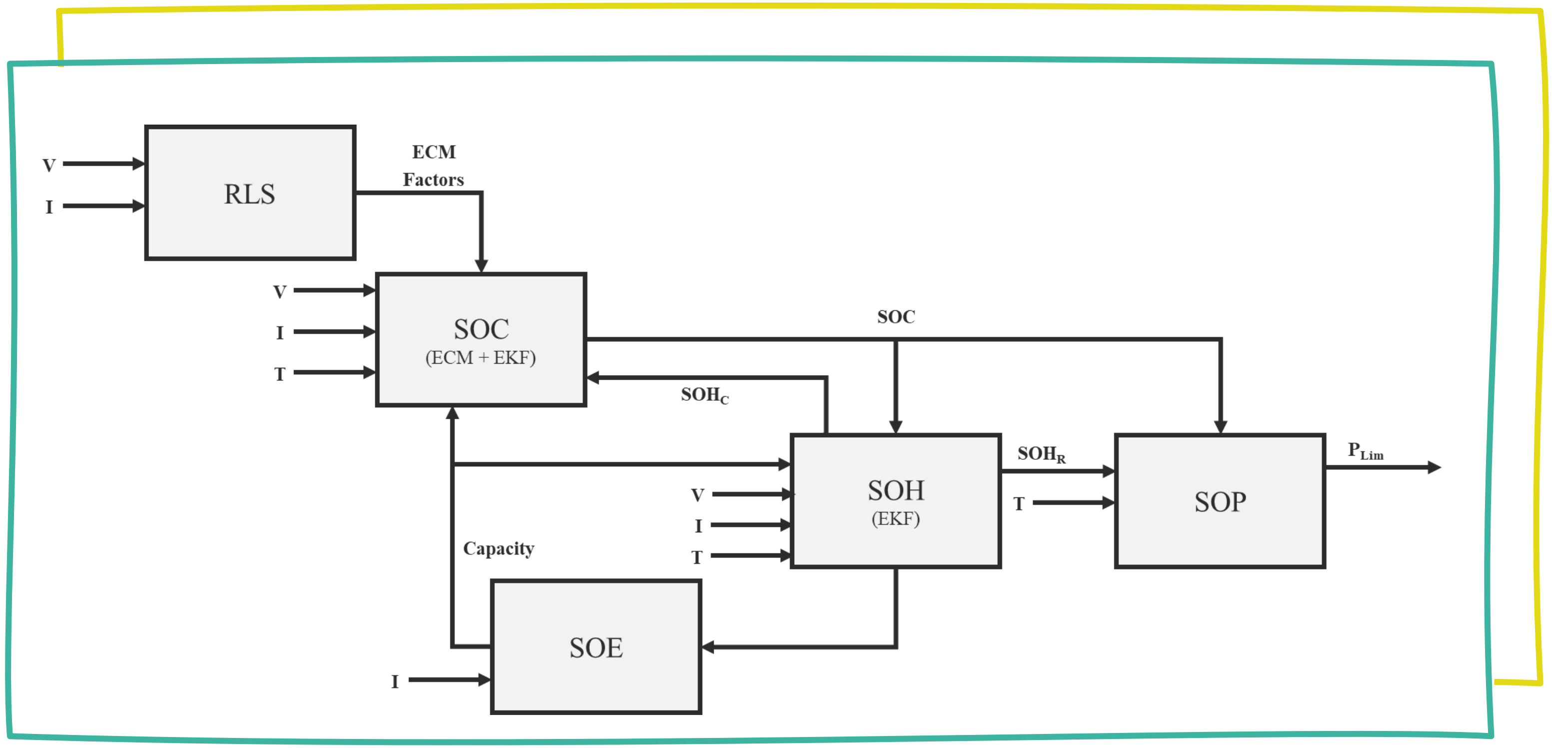


- Full scalable wireless BMS **up to 32 nodes**.
- **Individual tracking of SoX** for NMC and LTO cells
- Enabler for higher integration levels
- **Sweet spot identification** for heterogeneous batteries



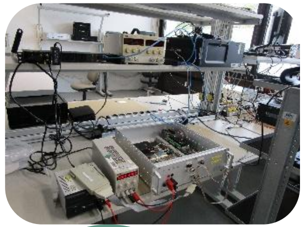
Edge Battery Pack SoX Structure

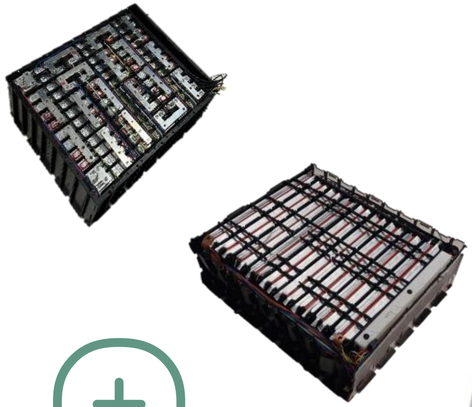


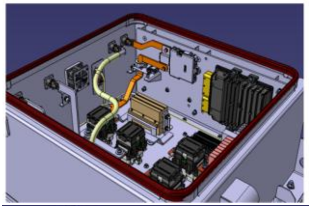


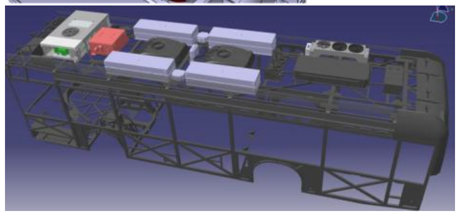
- ✓ **Individual tracking of SoX** for NMC and LTO cells
- ✓ Parametrization update **through cloud services**

HELIOS SCHAEFFLER









Q1
- Feature Implementation
- Close BSW

Q2
- HW Deliveries
- HIL Integration at Aahrus - Denmark

Q3/2024
- Module – Tubitak (TU)
- Housing – Bozankaya (TU)
- HW Validation Tests on cells

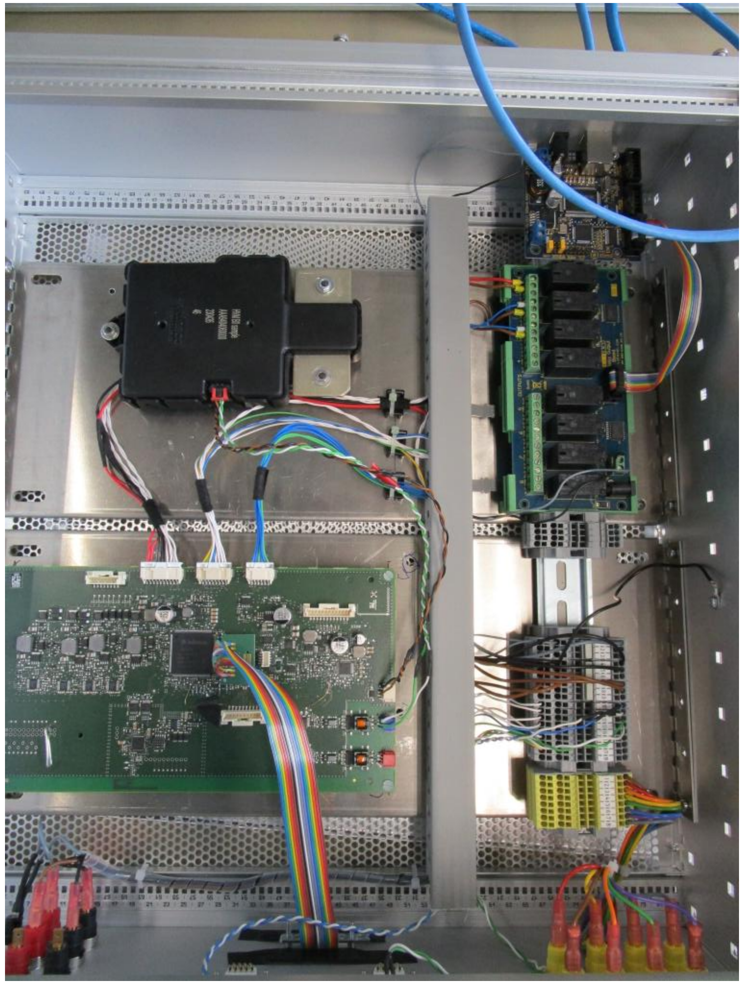
Q4/2024
- **Integration in BUS**
  - 32 Modules System
- Integration in i-MiEV
  - 12 Modules System

2025

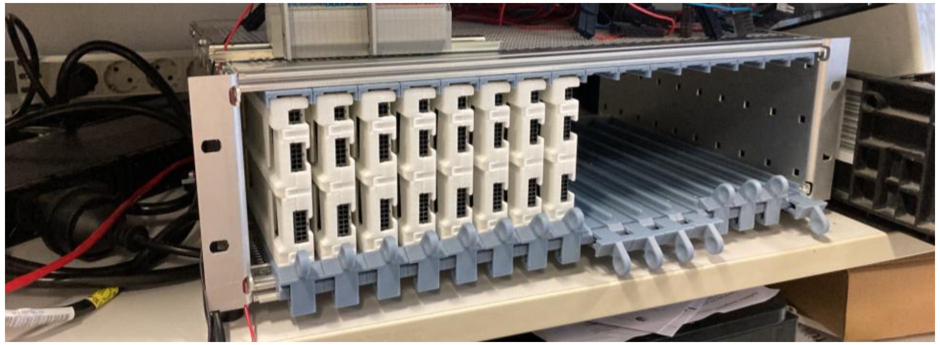
2024: Year of integration and validation

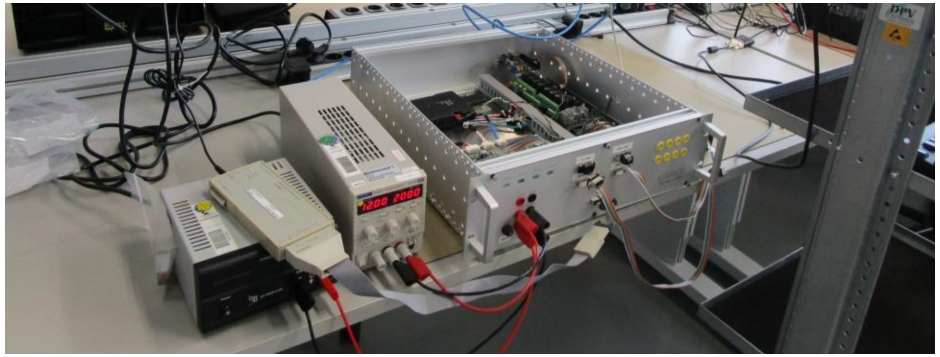
- **Integration into prototypes**
  - Construction of battery packs
  - Integration Passenger Car / EBus
  - Validation of Hybrid Concept of LTO and NMC modules

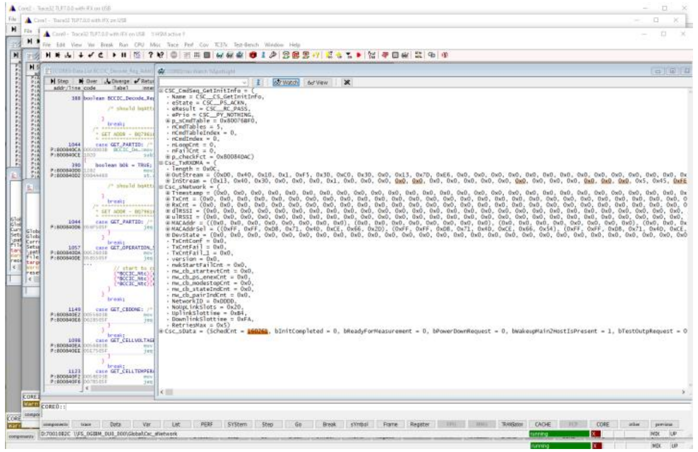
Test Bench for commissioning

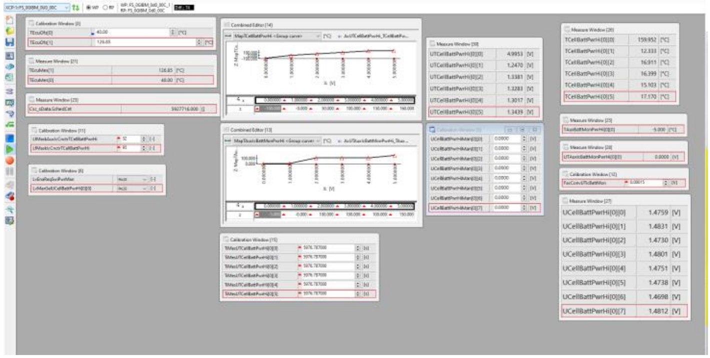


mTB Front View

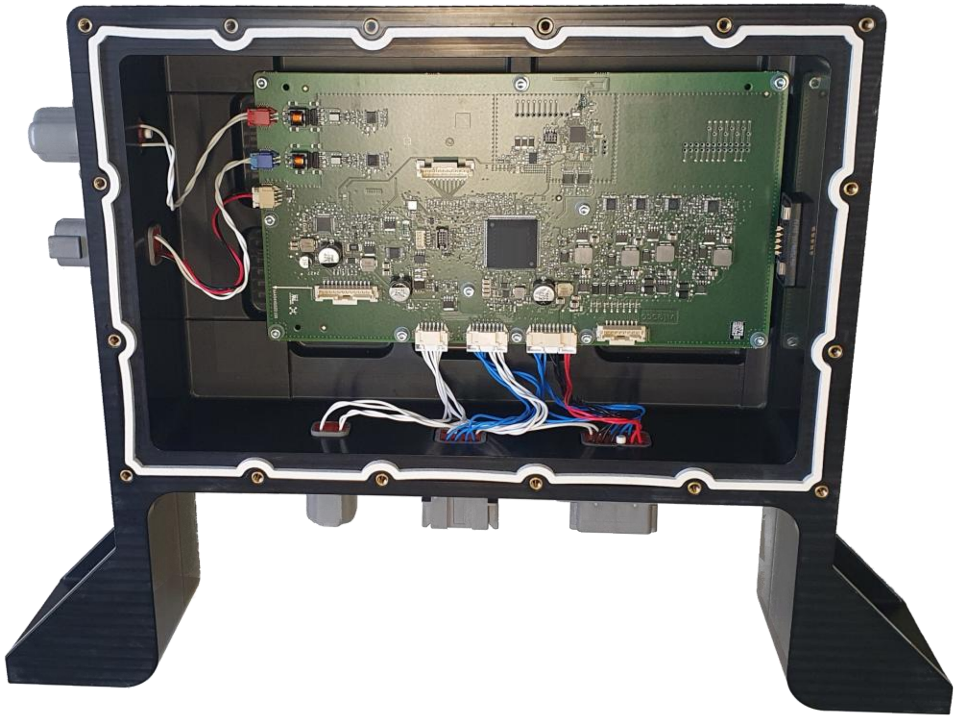


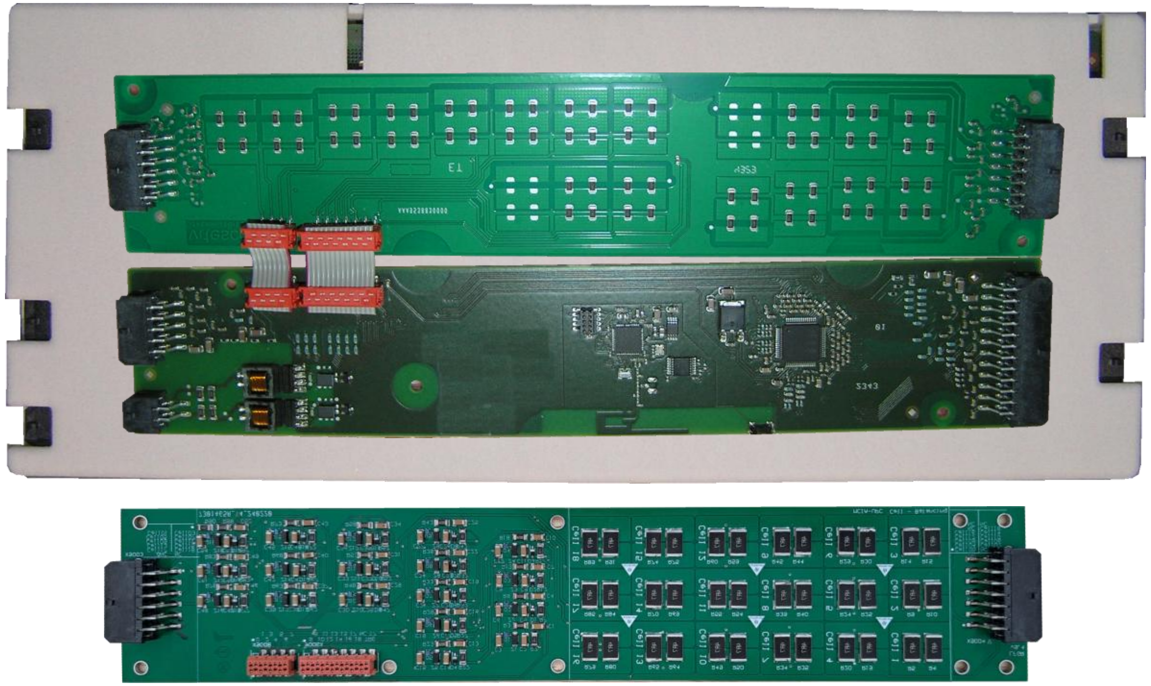






FLEXIBLE PCB FOR BALANCING



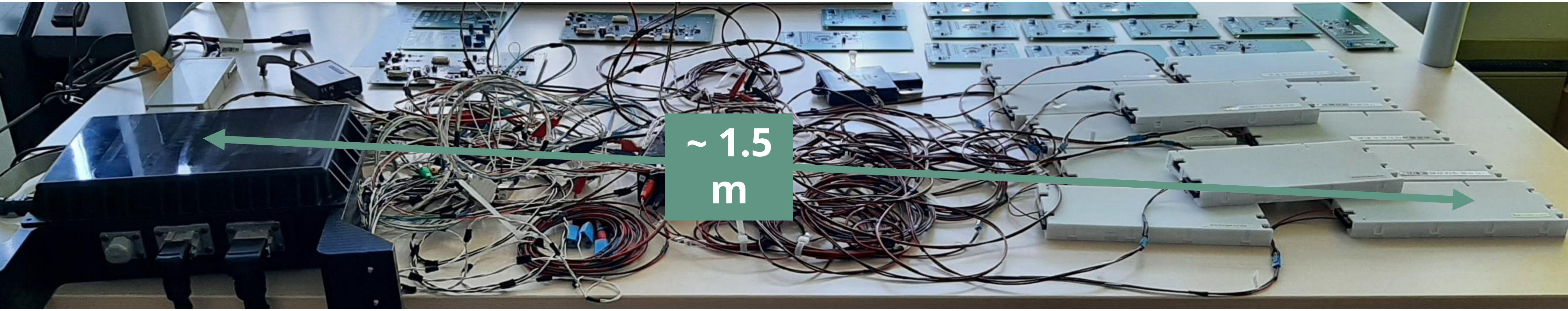


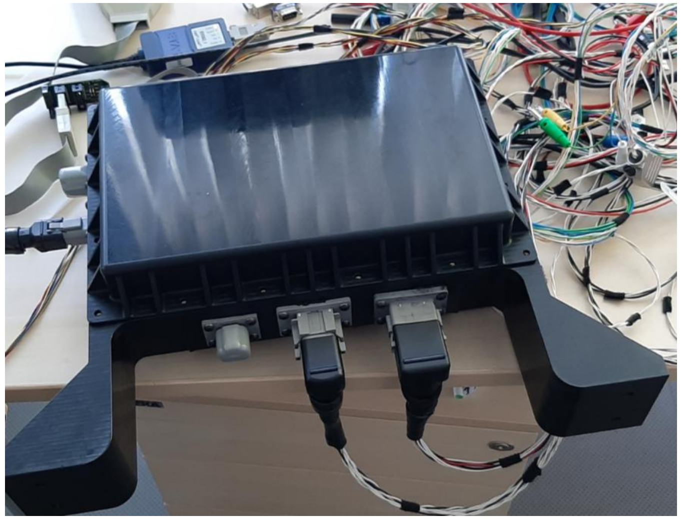
> Scalable and Modular CSC: Adapting different Passive Balancing Configurations

> CSC configuration: 32 nodes active, 16 cells per node → 512 cells

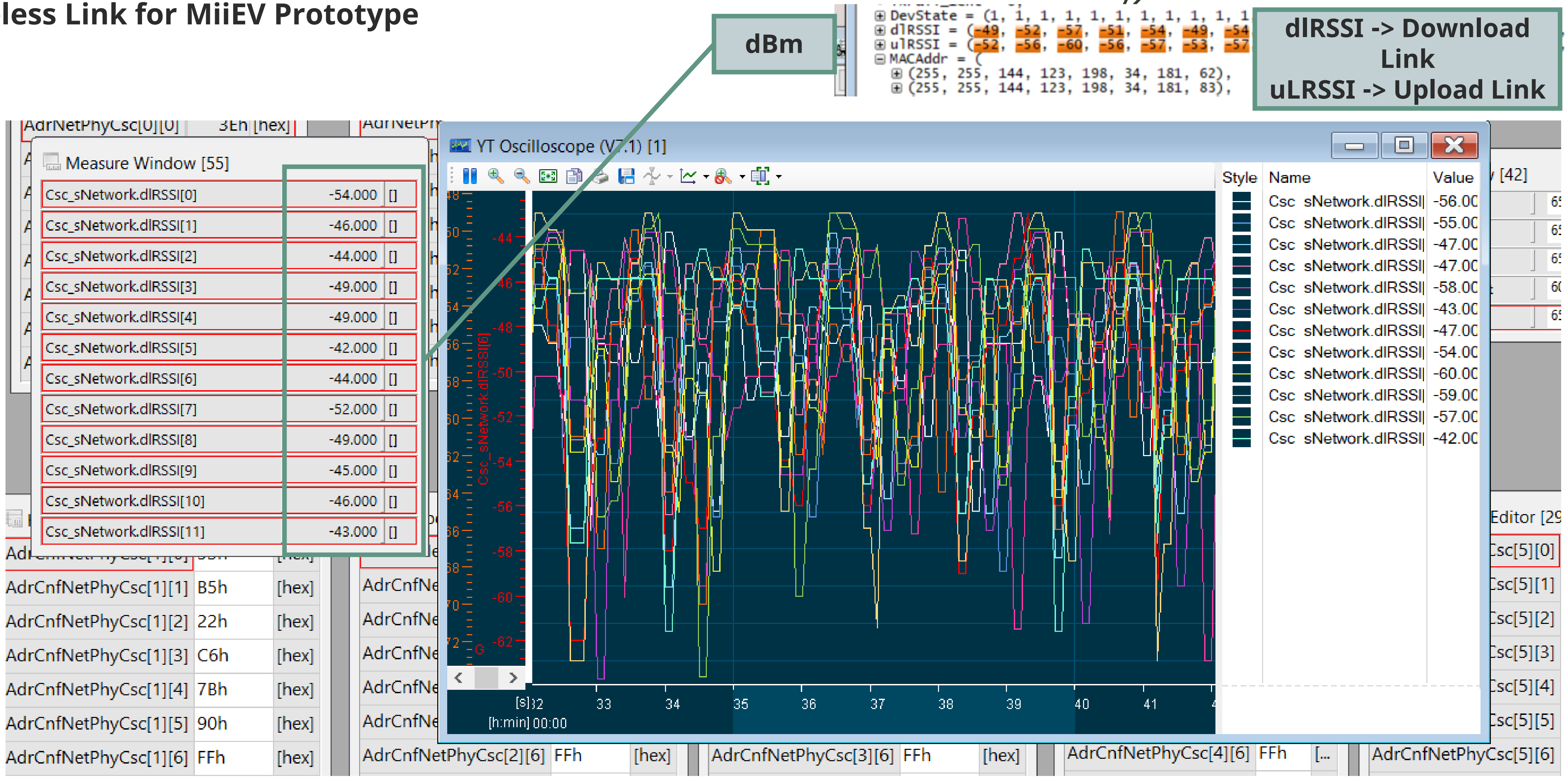
> Measurements: V, T within 100 ms. Others in low speed, but configurable

Wireless Link for MiiEV Prototype

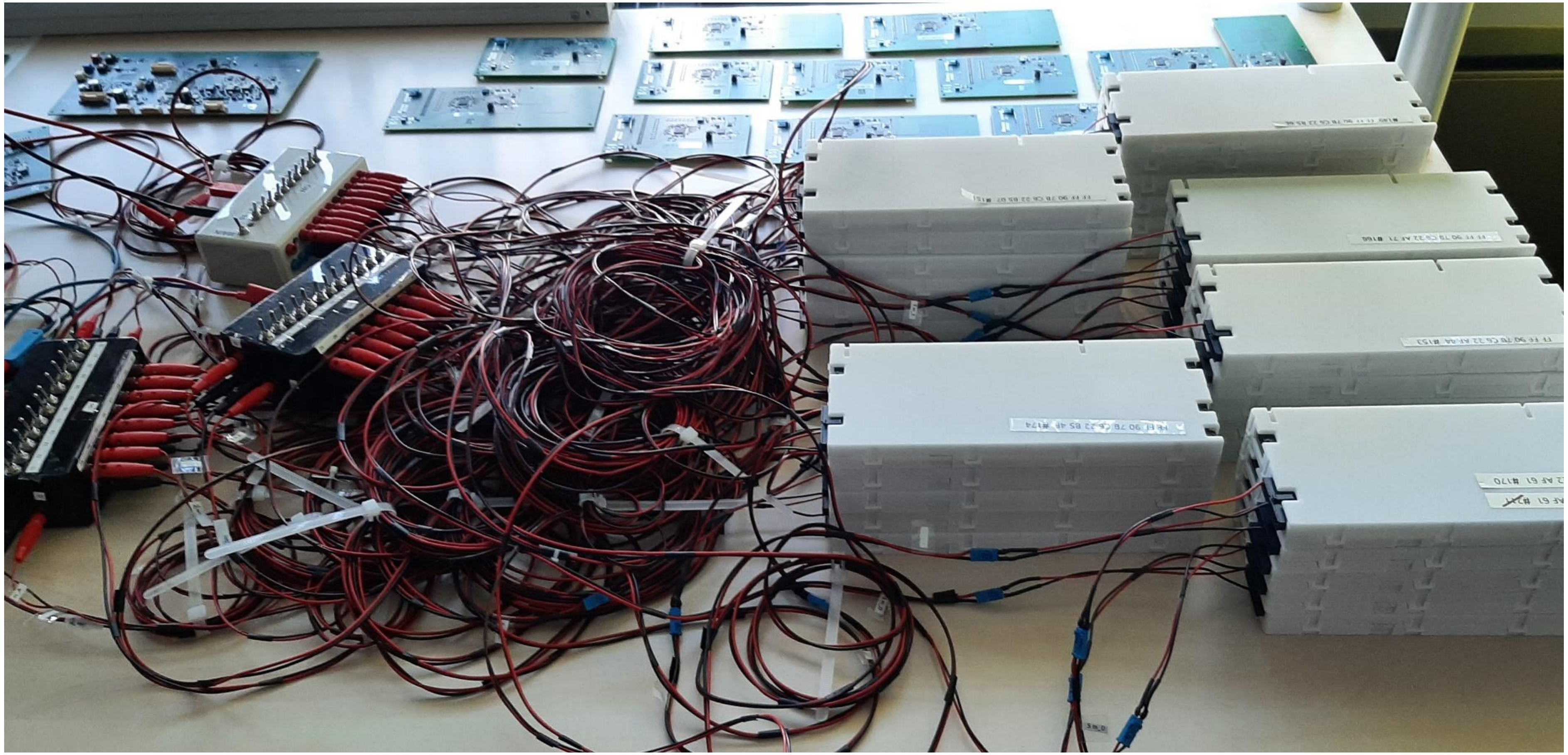




Wireless Link for MiiEV Prototype

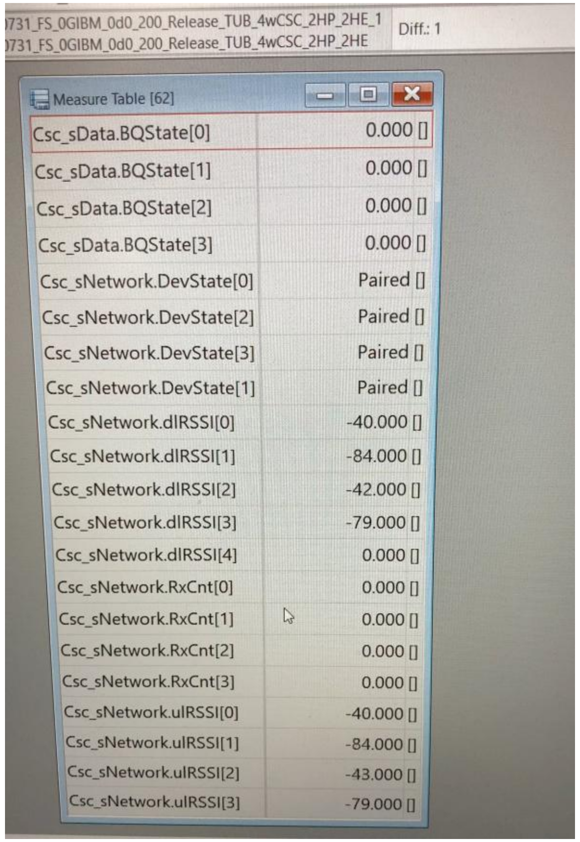


Wireless Link for EBus Prototype



VIDEO

> **Wireless capability by 10 meters within 2 rooms**
>
> > Proof of wireless communication by 1st setup (GA#8 – July 2024)
> >
> > 4 wireless nodes alive and running – 1 connected to modules



Q&A

https://helios-h2020project.eu/

info@helios-h2020project.eu

@helios_h2020

helios-h2020

This project has been co-funded by the European Union's Horizon 2020 research and innovation programme under grant agreement no 963646. This document reflects the view of its author(s) only. Neither the European Commission nor the funding agency are responsible for any use that may be made of the information it contains.

juan.alberto.romero.baena@vitesco.com

SCHAEFFLER

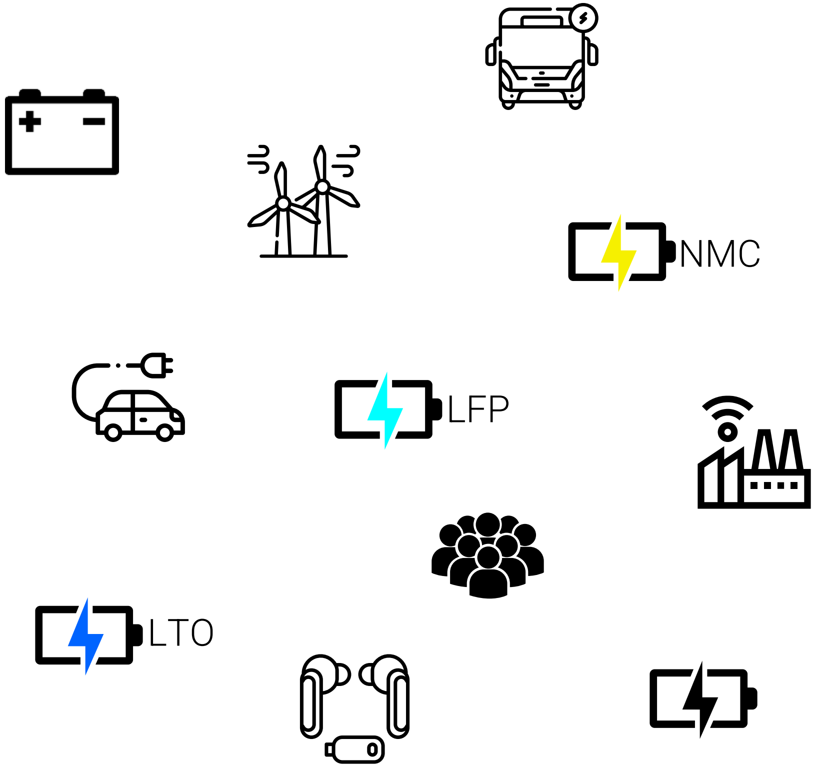
Advanced SoX algorithms using transfer learning from real-time operating data

BMS: The brain of batteries

Lightweight Battery System for Extended Range at Improved Safety

LIBERTY has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 963522. The document reflects only the author's view, the Agency is not responsible for any use that may be made of the information it contains.

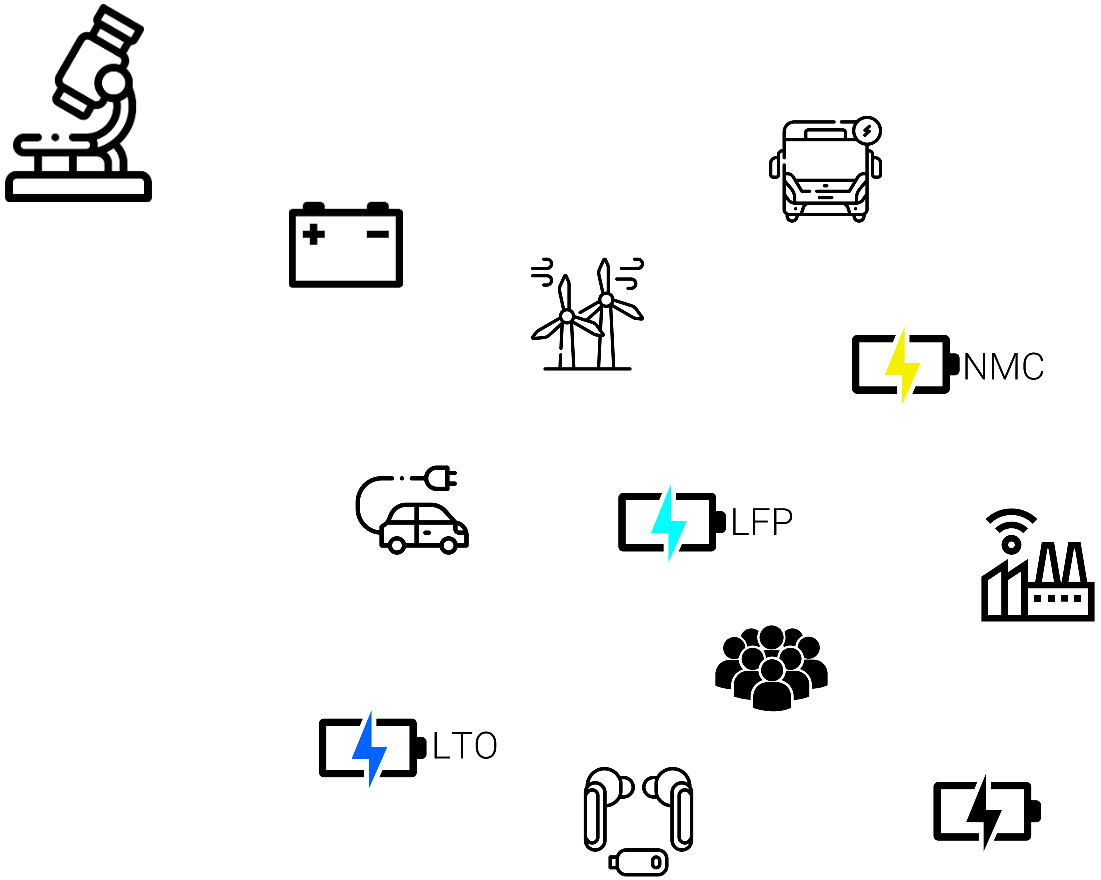
SOX Estimation Algorithms



SOX Estimation Algorithms

Every time a new SoC/SoH model has to be made for a new cell, application, etc.

all the tests must be done from scratch.



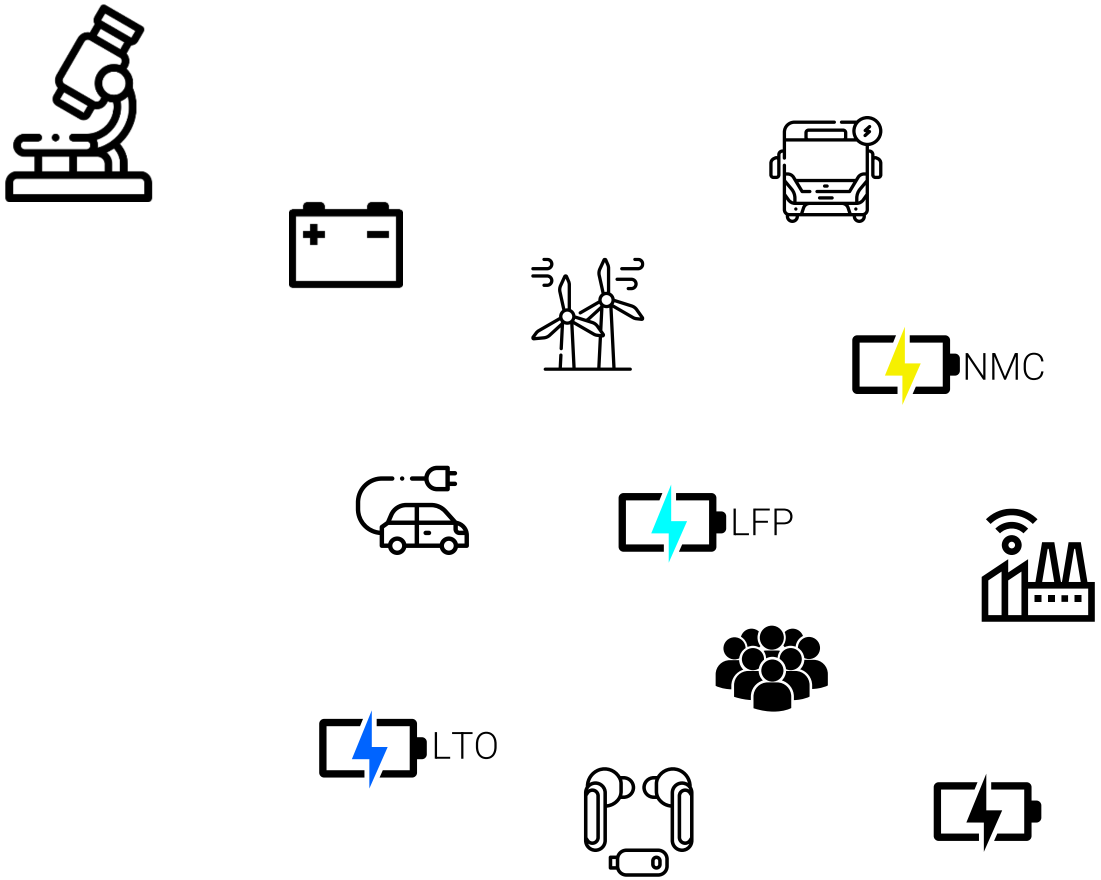
SOX Estimation Algorithms

Every time a new SoC/SoH model has to be made for a new cell, application, etc.

all the tests must be done from scratch.

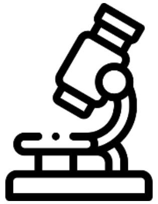
Main Requirements:

- Universal SoX algorithm
- Quick model development phase
- Reduced experimental burden



SOX Estimation Algorithms

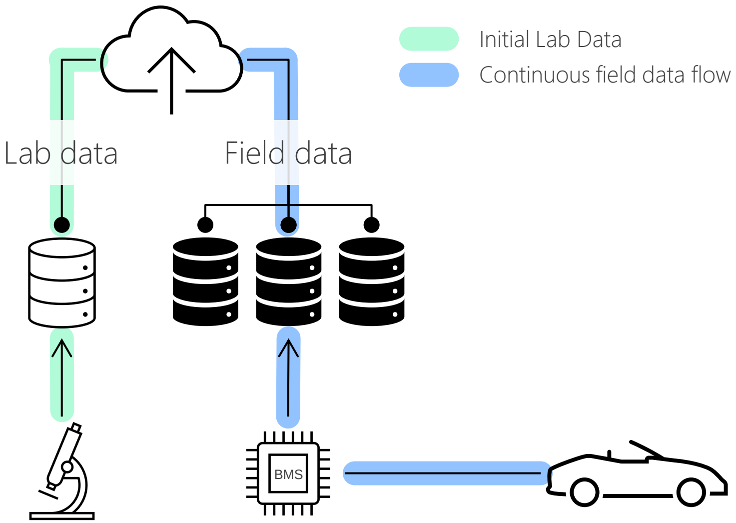
Every time a new SoC/SoH model has to be made for a new cell, application, etc.
all the tests must be done from scratch.



Main Requirements:

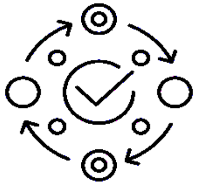
- Universal SoX algorithm
- Quick model development phase
- Reduced experimental burden

SOX Model Training



Is it possible to:

- Use data from other cell references or chemistries to create a model?
- Take advantage of in-field operation data for SoX estimation modelling improvement?



SOX Estimation Algorithms

Methology:

Virtual dataset

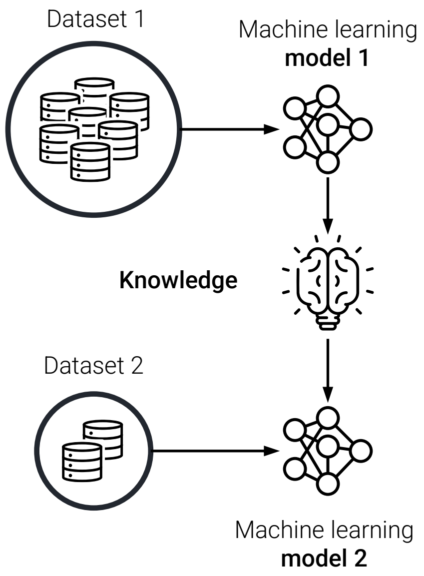
- Allow to use a broad dataset with the meaningful trends to be adapted by transfer learning
- Rich variety of conditions can be emulated with generic electrochemical models

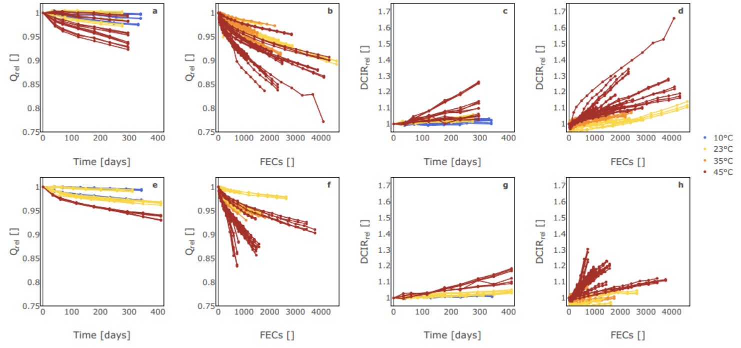
Data-driven retraining:

- Take advantage of field operation data to improve algorithms, thus increasing accuracy and reliability.
- Native procedure of this technology make it more efficient.

Transfer learning technique

- The amount of experimental testing to tune first algorithm can be limited (before including field data).



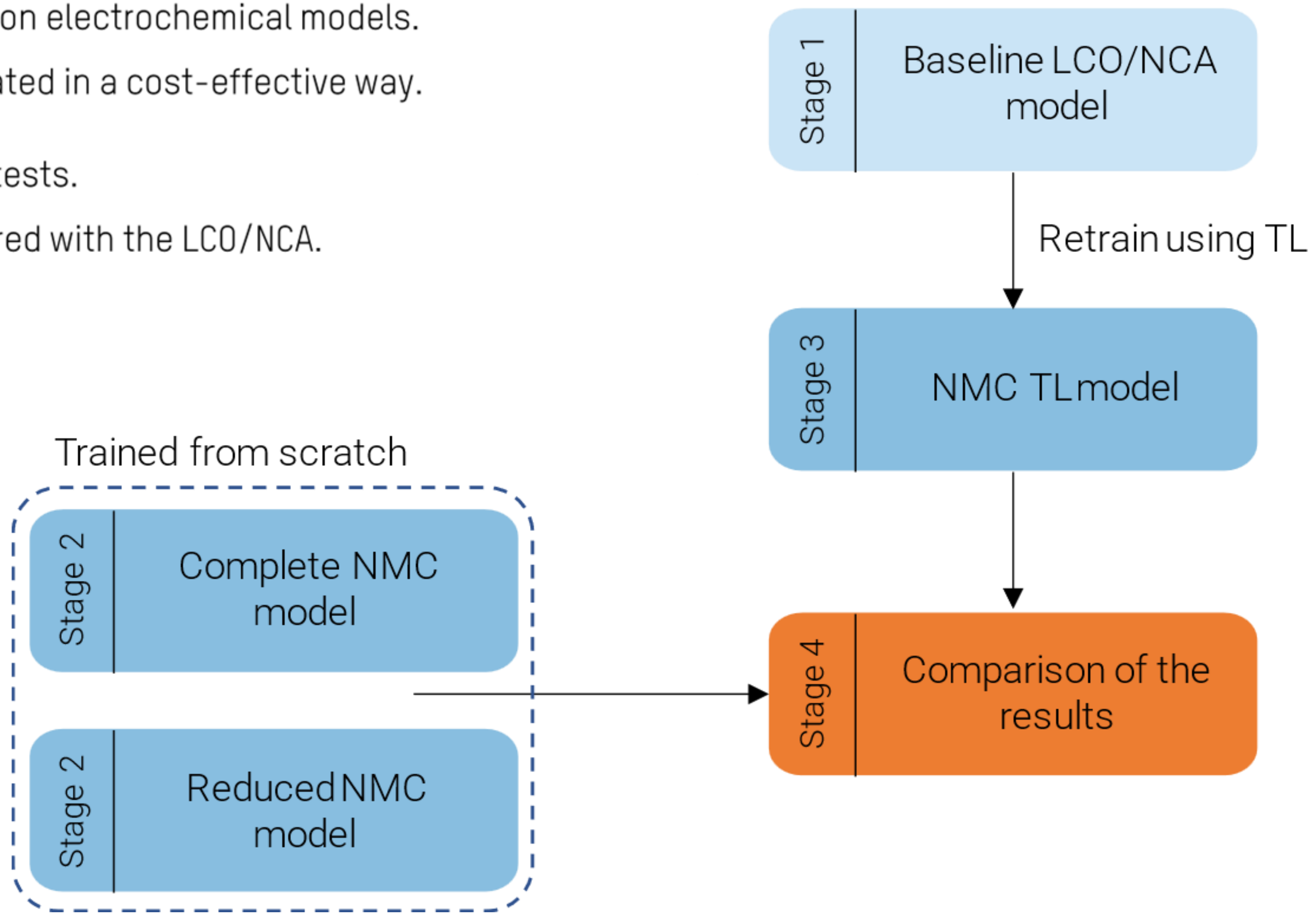


Stroebl, F., Petersohn, R., Schricker, B. *et al.* A multi-stage lithium-ion battery aging dataset using various experimental design methodologies. *Sci Data* **11**, 1020 (2024)

SOX Estimation Algorithms

Dataset

- **LCO/NCA dataset:** based on electrochemical models. Lots of conditions simulated in a cost-effective way.
- **NMC dataset:** laboratory tests. Reduced dataset compared with the LCO/NCA.



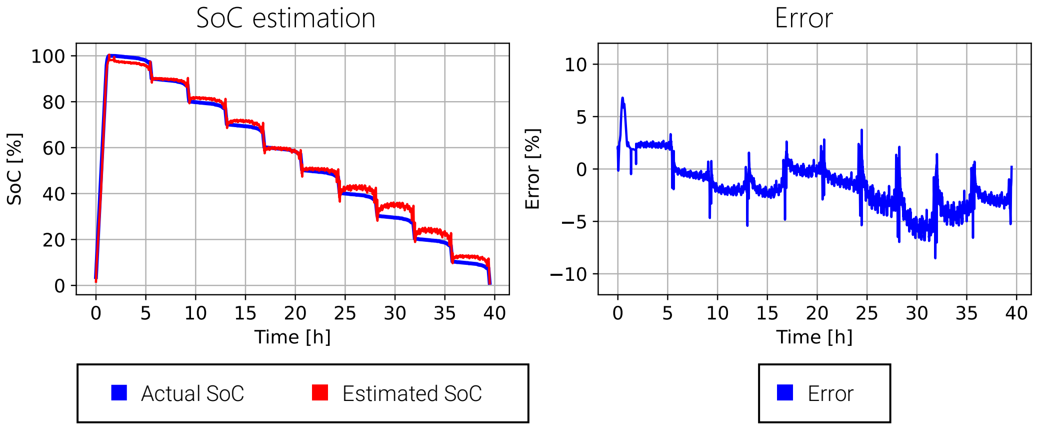
- Trained with LCO/NCA cell data
- Trained with NMC cell data

SOX Estimation Algorithms

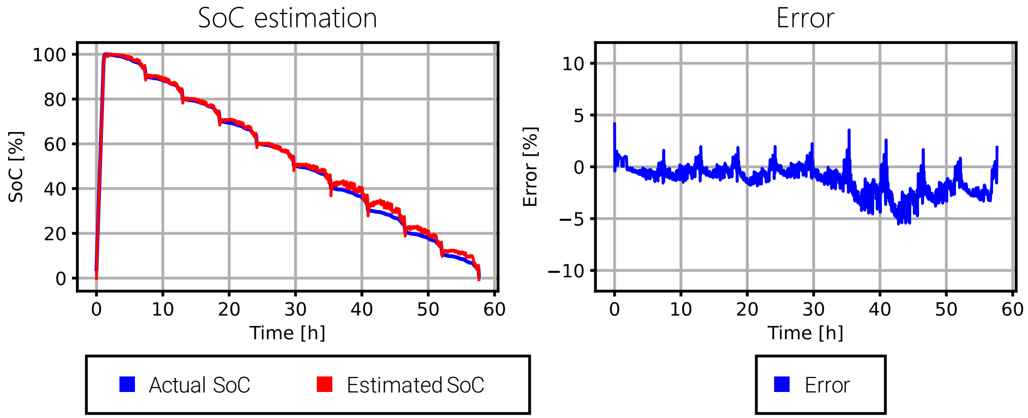
SOC algorithm results:

- TL model showcases a superior algorithm performance compared to the model trained from scratch.
- TL model shows a more robust respond while achieving lower MAE and much lower Max. Error.
- TL model uses the pre-existing knowledge acquired during the training of the baseline model.

Reduced NMC model: Test results



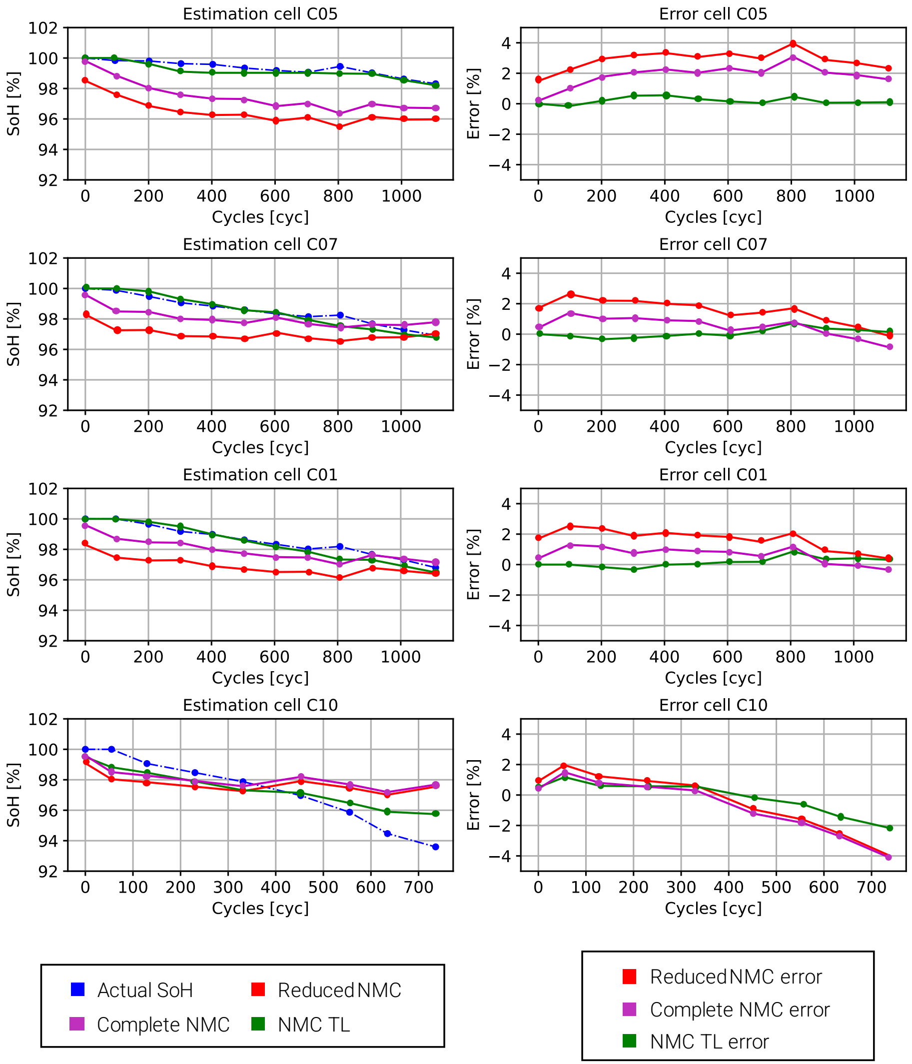
TL model: Test results



SOX Estimation Algorithms

SOH algorithm:

- TL model outperforms the model trained from scratch, delivering superior results and enhanced robustness.
- Certain scenarios remain untested, prompting the exploration of algorithmic responses to highly degraded cells.
- TL as an effective strategy, emphasizing improved results, and shorter training times.



SOX Estimation Algorithms

CONCLUSIONS

- SoX estimation algorithms benefit from TL to enhance adaptability, performance, and efficiency.
- The methodology serve as a basis for SoX algorithm development, ensuring consistency and reproducibility.
- TL model outperforms the models trained from scratch, requiring 50% less data, delivering superior results and enhanced robustness.
- TL shows as an effective strategy, emphasizing reduced data requirements, improved results, and shorter training times.

MARBEL

Manufacturing and assembly of modular and reusable EV battery for environment-friendly and lightweight mobility

Revolutionizing Performance and Sustainability in the Next-Generation of Battery Management Systems

PRESENTER NAME: Sergi Obrador Rey
EMAIL: sobrador@irec.cat

DATE: 26th November 2024

INDEX

MARBEL

Introduction

MARBEL Framework

Electric Vehicle Batteries Supply Chain

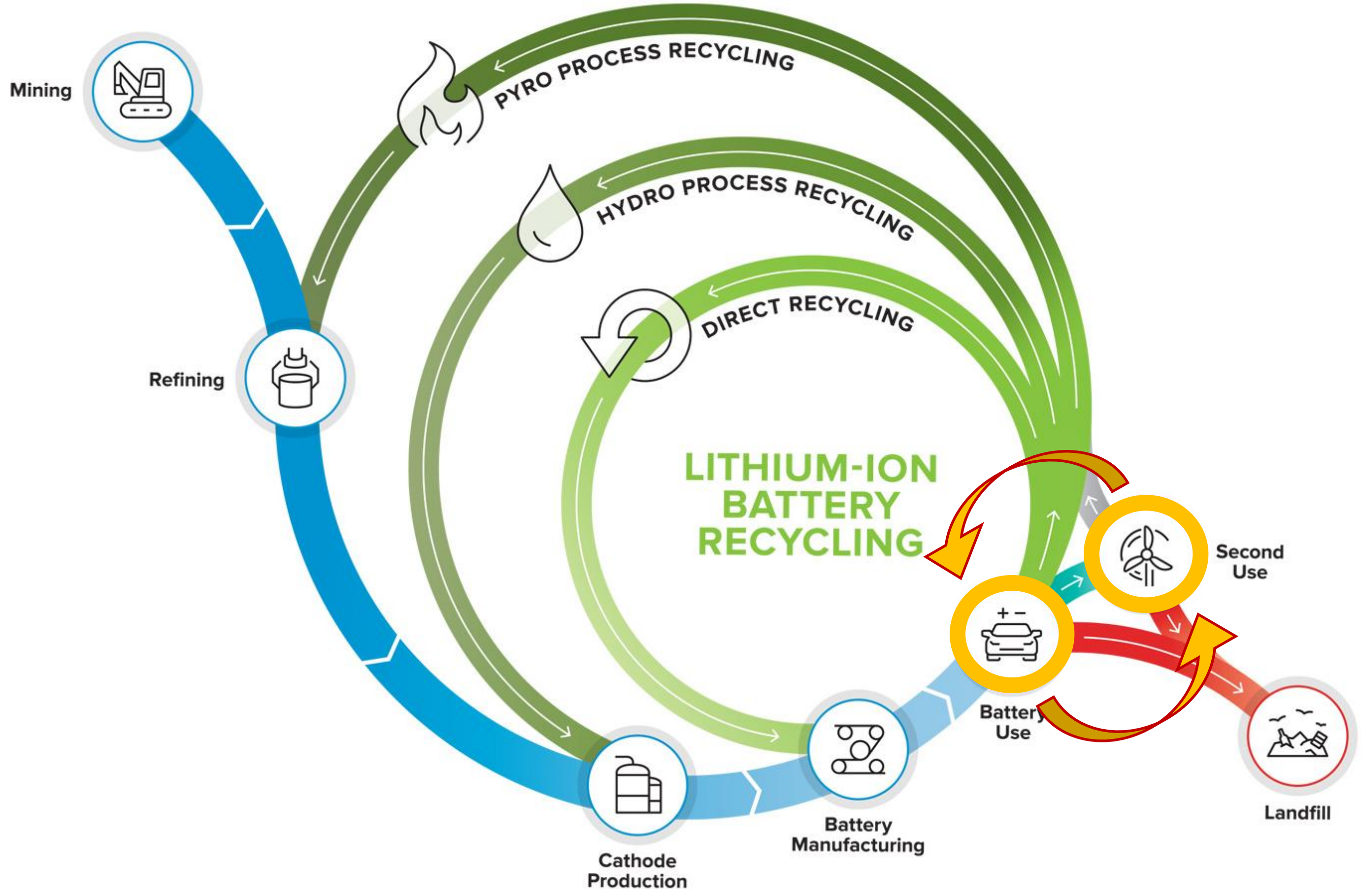


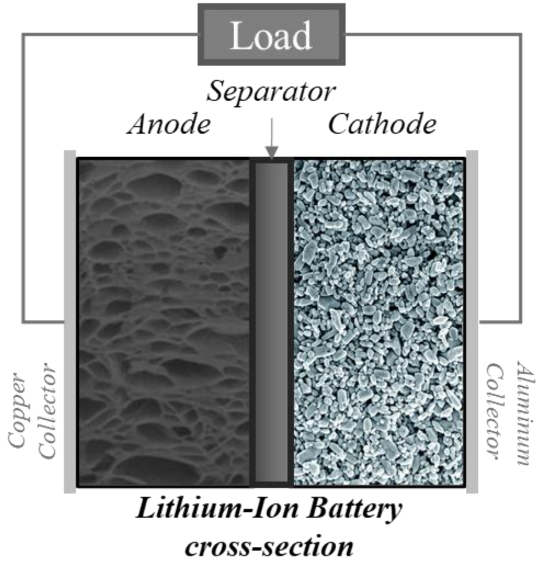
Figure 1.- EV Batteries Supply Chain.
Source: Argonne National Laboratory (anl.gov)

Problem Statement

Battery Management Systems Requirements

Electric Vehicle Batteries SW Complexity - Modelling

Provide better insights to Increase Performance



Performance Enhancement
State-of-Charge (**SoC**)

Better-End-of-Life Definition
State-of-Health (**SoH**)

Decisions in 1st Life & Beyond
Remaining-Useful-Life (**RUL**)

Mathematical
White-box Modelling

Mix
Grey-box Modelling

Data-Driven
Black-box Modelling

Battery Management Systems Requirements

Electric Vehicle Batteries HW Complexity From Pack-to-Cell

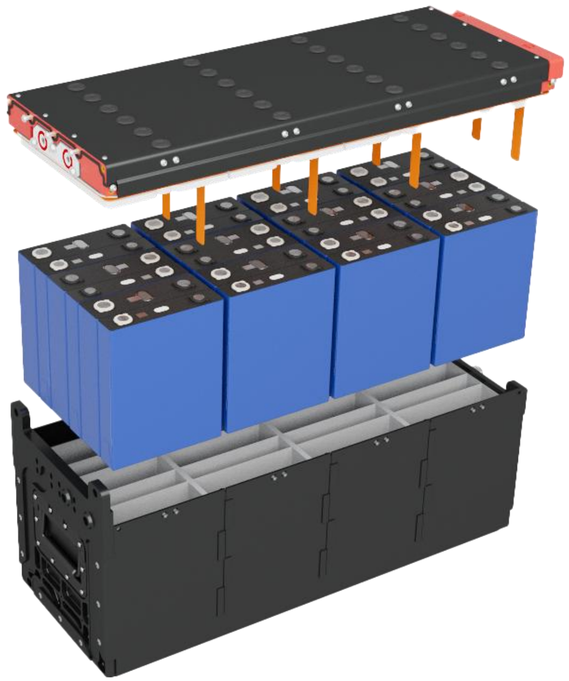


Figure 2.- Battery Module Layout.
Source: News and media (rocktechnology.sandvik)

Between 100-200 cells

Many Sensors!!

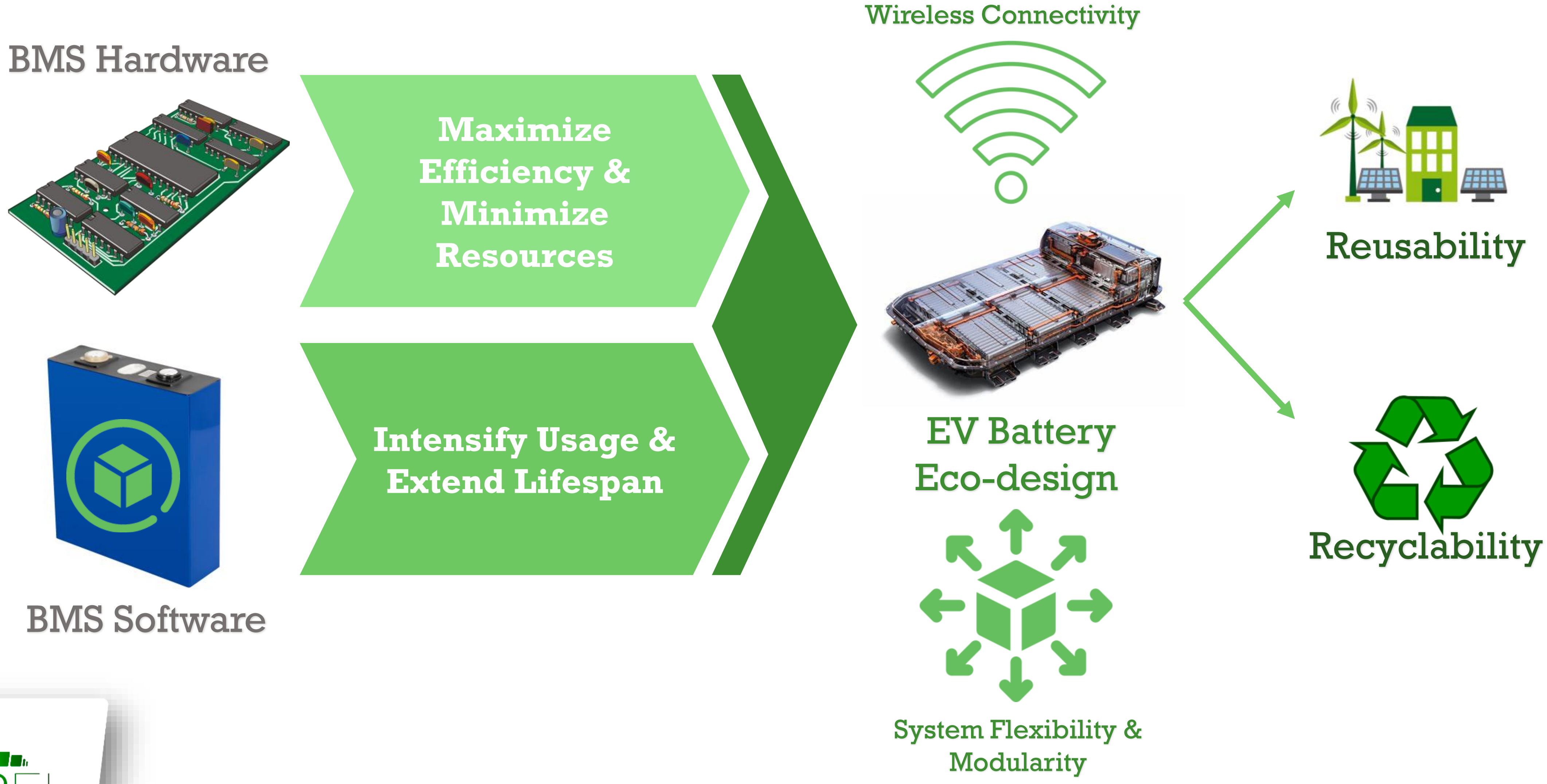
Temperature
Voltage
Current
Protections
Stress Gauge
Pack-Isolation

MARBEL

Proposal

Advanced Battery Management System

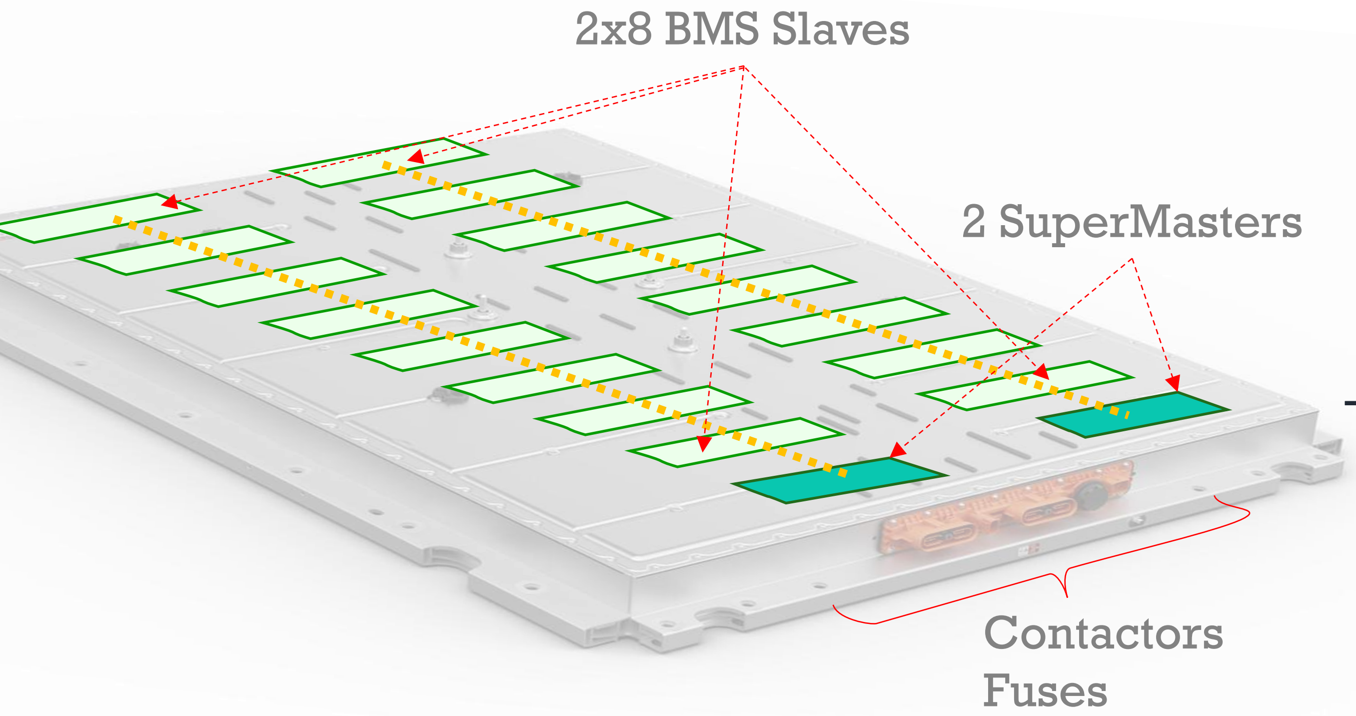
Eco-design Oriented



MARBEL

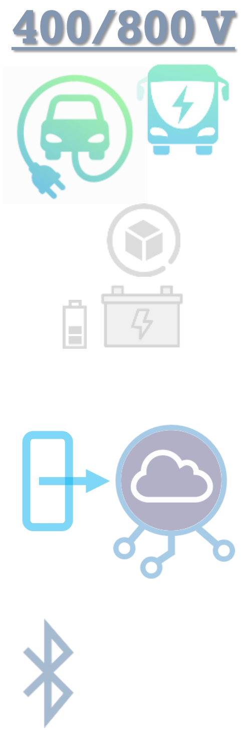
BCU/BMU Configuration

Scalability in 1st life



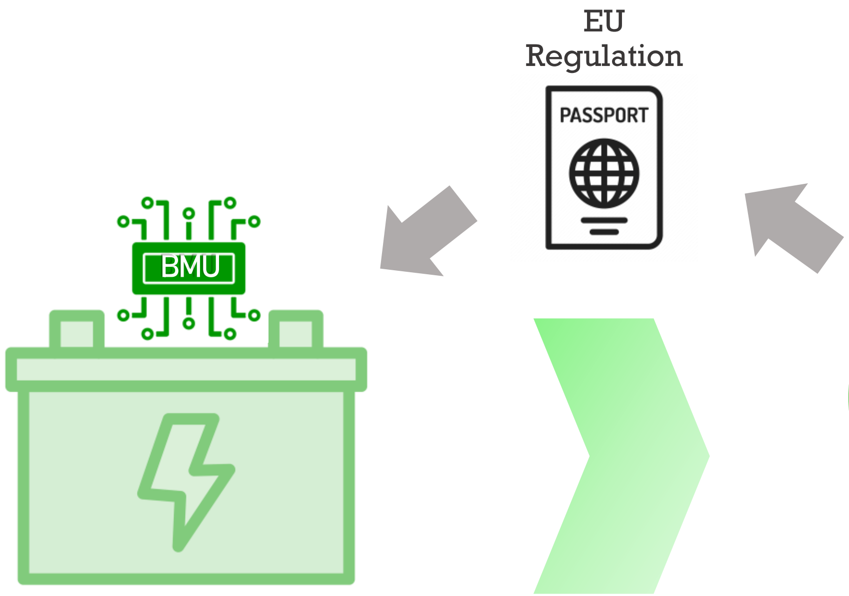
Functionalities

- **Junction Box** →
- **Control Optimization** →
- **External COMMS** →
- **Internal COMMS** →



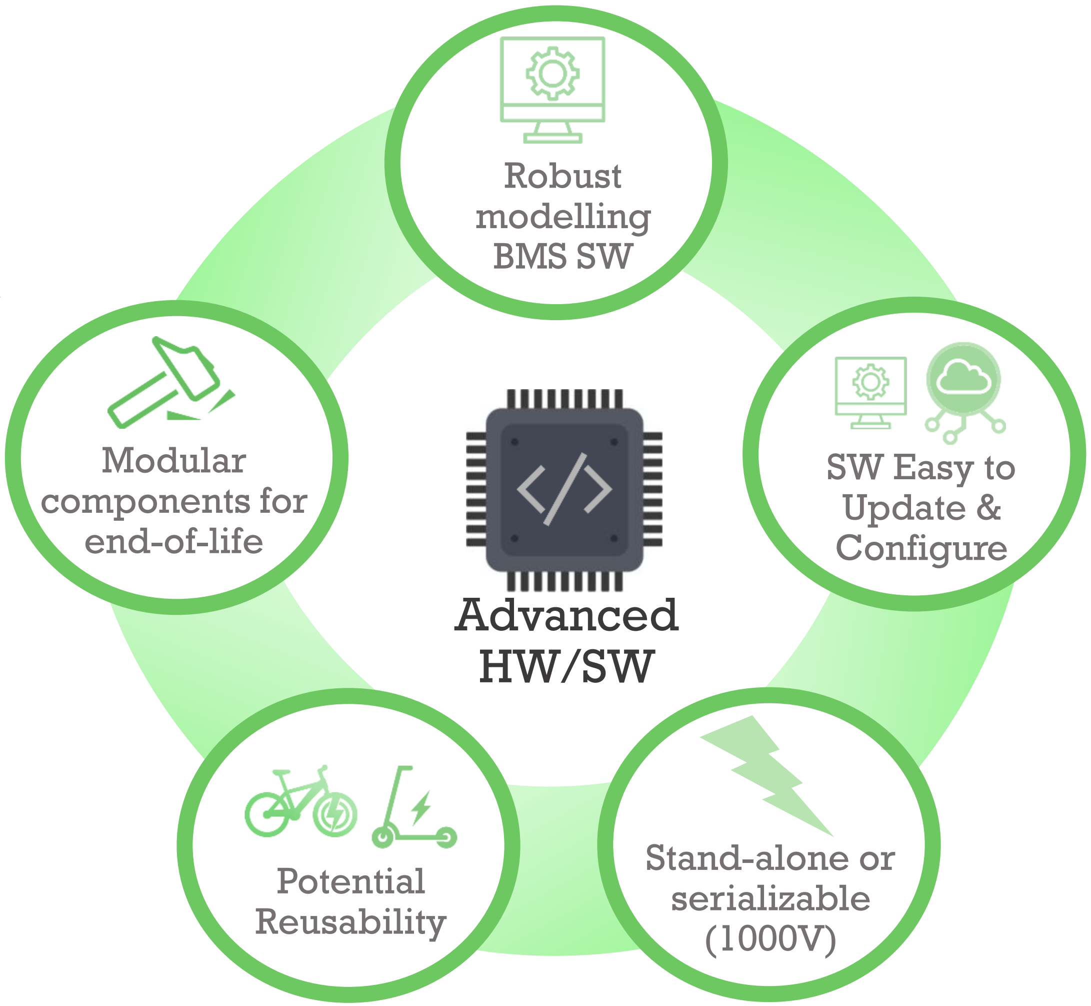
BMU Slave-Units Potential

Modularity & Flexibility, Design Priority



Battery Module Slave

6 up to 16 Cells



Conclusions

Conclusions

MARBEL Advanced Battery Management System

- **Eco-Design** Oriented Development of a full-operative **EV Battery Module** of High TRL
- System designed based on **industry standards**, likely to be well-received in the **market**.
- **Cloud-based** architecture developed in the project proves its effectiveness and can potentially set the standards for the **next generation of BMS**.

Future Work:

- Test Final Batteries (On-going)

- Improve Hybrid modelling advanced approach

- Study the applicability of different 2nd Life scenarios

MARBEL

Manufacturing and assembly of modular and reusable EV battery for environment-friendly and lightweight mobility

THANK YOU!

PRESENTER NAME: Sergi Obrador Rey
EMAIL: sobrador@irec.cat
DATE: 25th November 2024

A project coordinated by:
eurecat

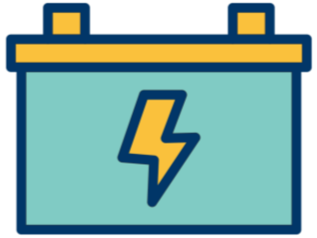
Backup

MARBEL Framework

Electric Vehicle Battery System Eco-design alignment

ECO-DESIGN PRINCIPLES

Minimize Energy & Material Consumption
Select Low Impact Resources
Facilitate Disassembly
Optimize Product Lifetime
Extend Material Lifespan



MARBEL

Smart Cell Manager (iSCM) Specification

Low power wireless communication technology

Premises:

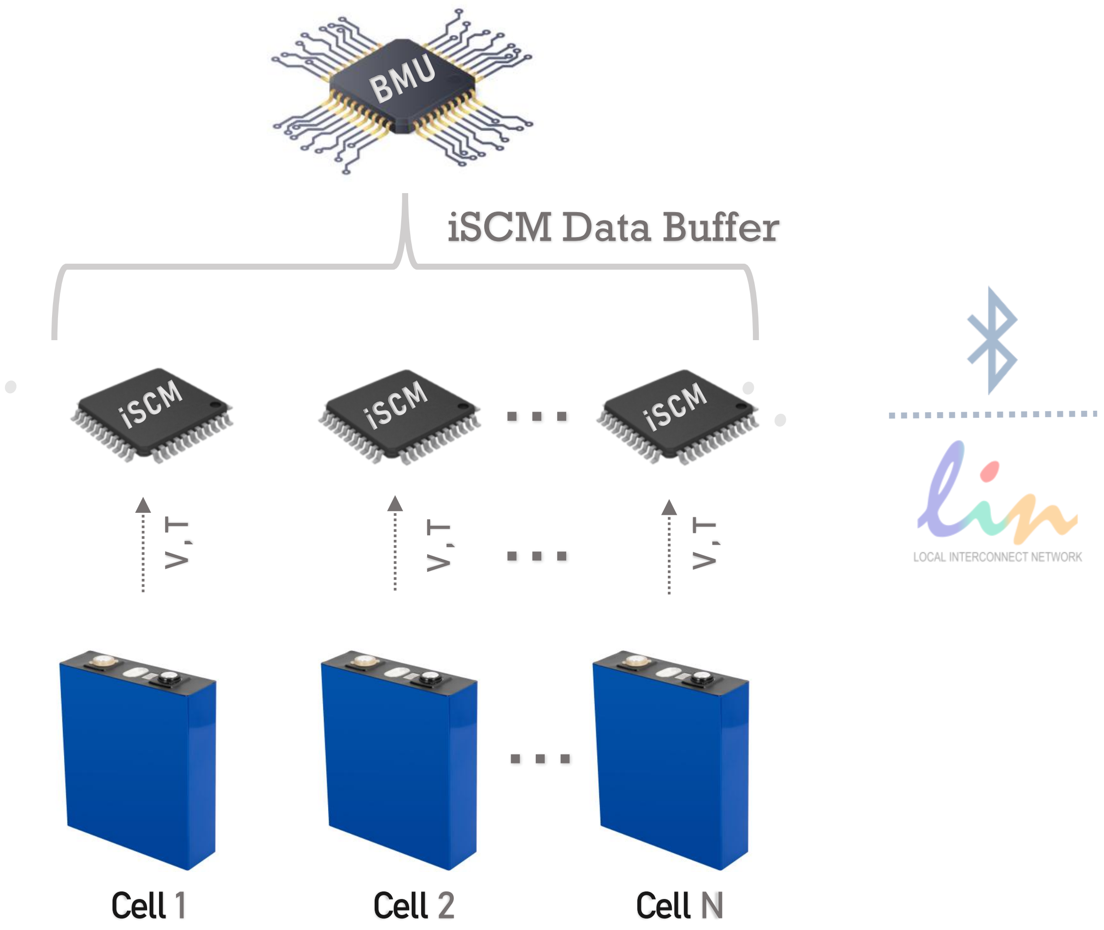
Small & Compact ⟶ Fit in BMU designs

Wireless Communications

Low Power demand

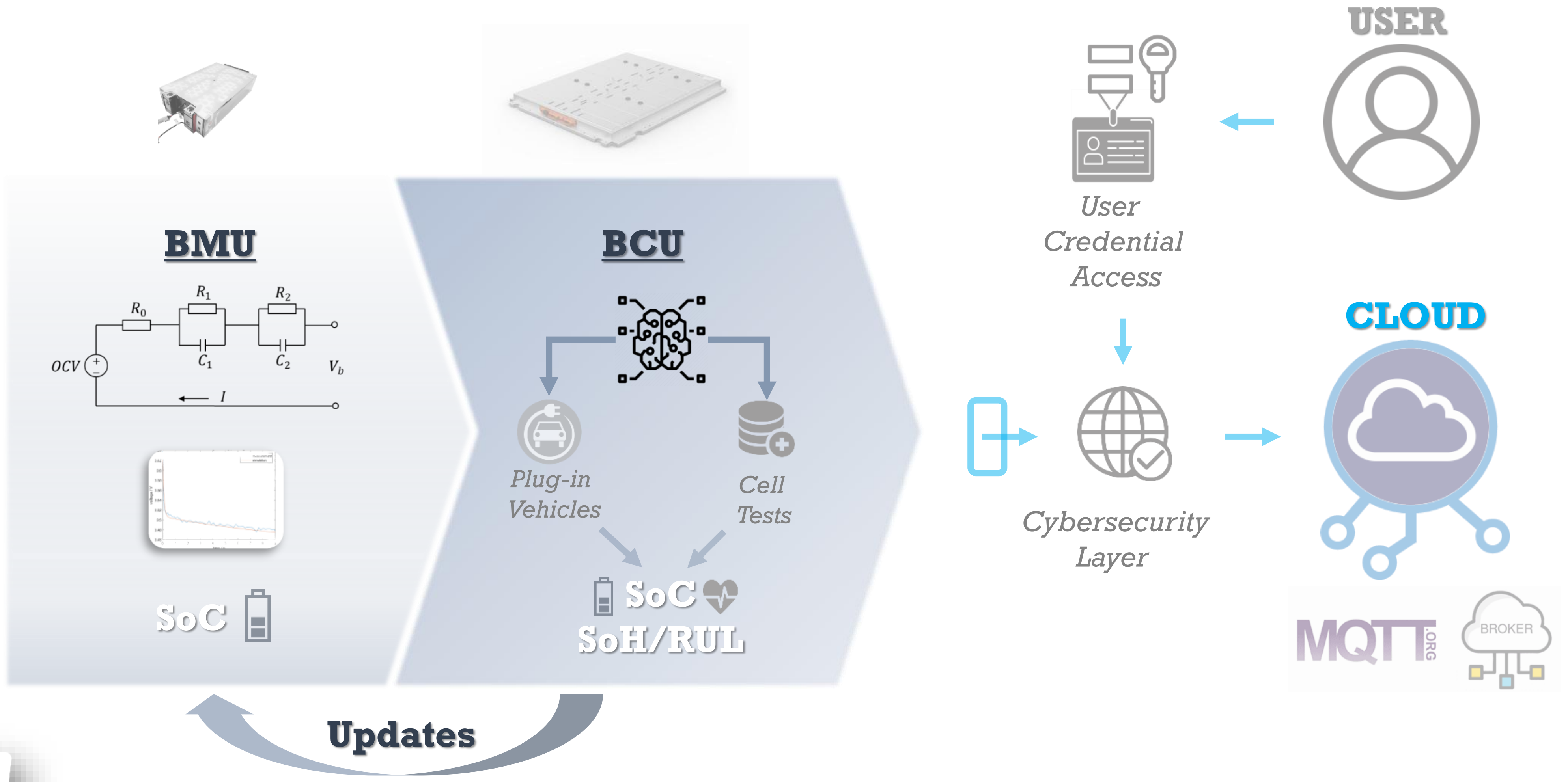
Cost-Effective Solution

Compatibility with EV standards



Battery Management System Modelling Software

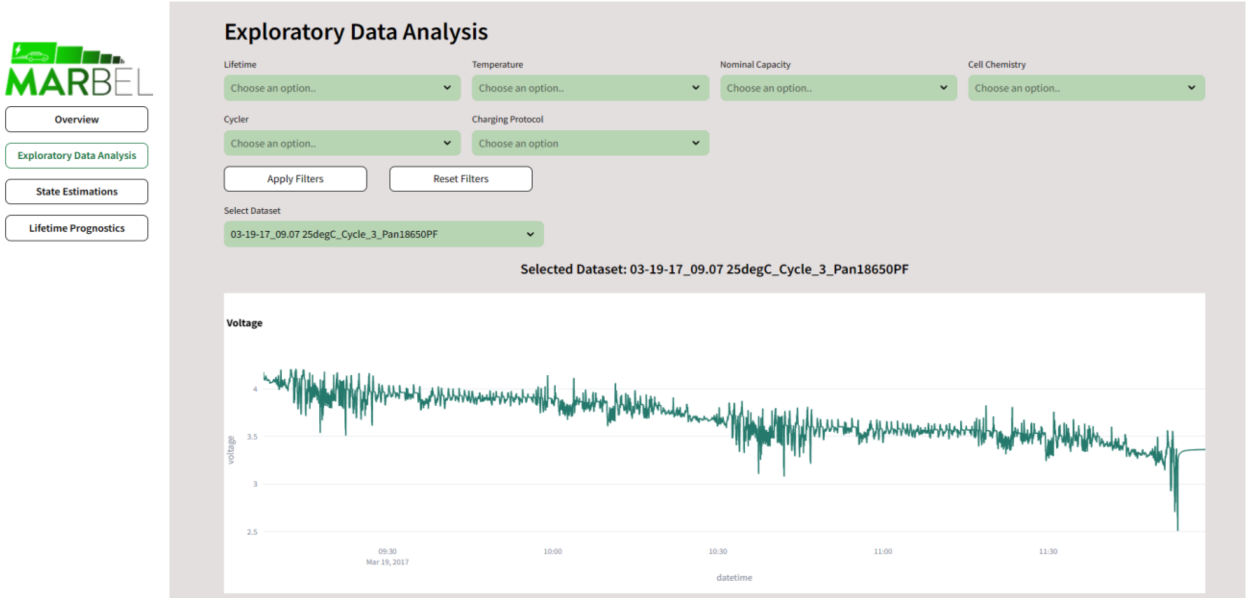
From Equivalent Circuit Models to Machine Learning



MARBEL

Battery Management System Modelling Software

User Interface



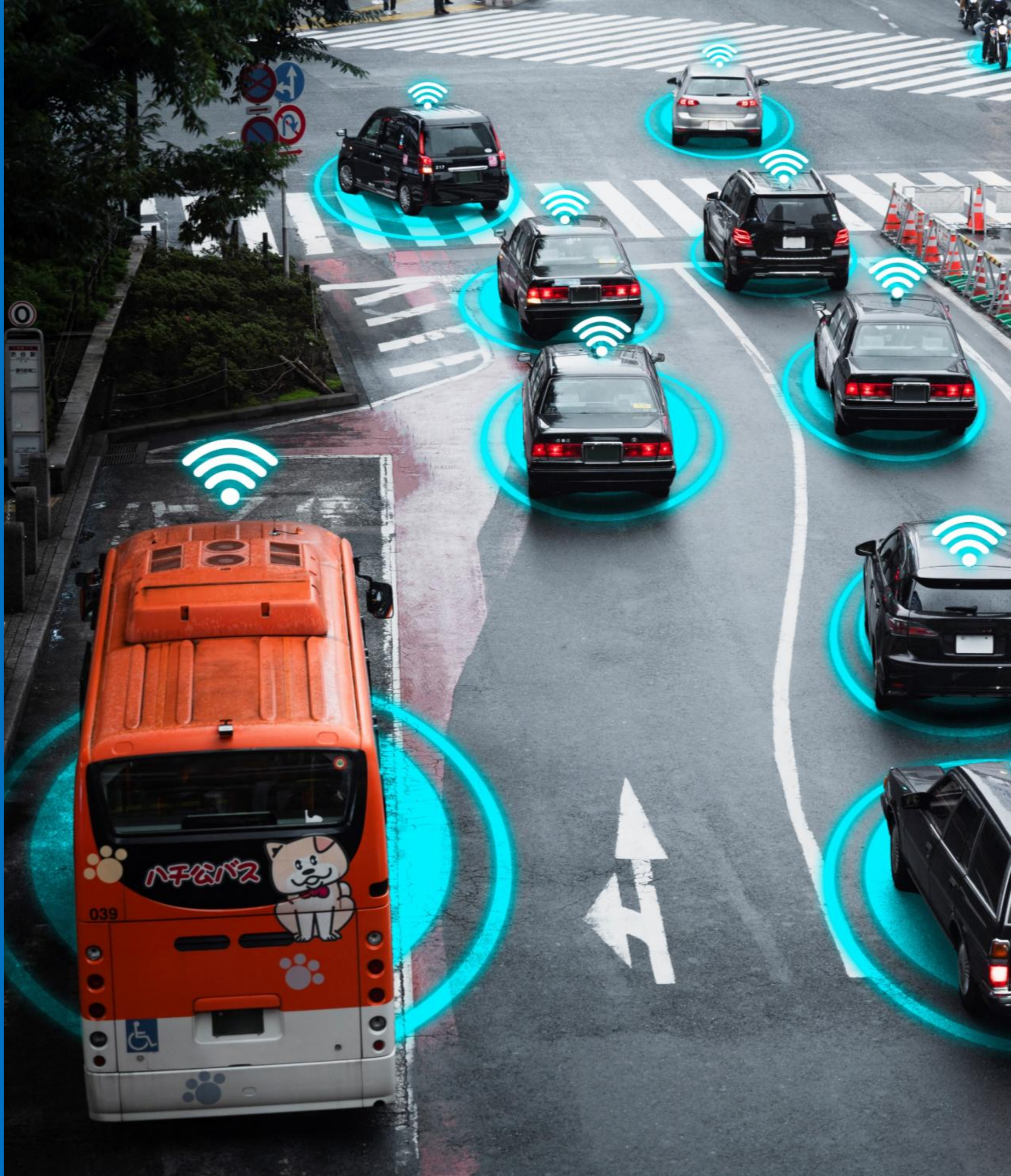
iBattMan

Smart, Connected and Secure Battery Management System Enhanced by Next-Generation Edge- and Cloud-Computing, Sensors and Interoperable Architecture

COLLABAT Next-Gen EV-Battery Solutions Showcase
Nov 26, Barcelona

Corneliu Barbu, Associate Professor,
Aarhus University

Co-funded by the European Union Horizon Europe programme (HORIZON-CL5-2023-D5-01). Under Grant agreement n. 101138856.

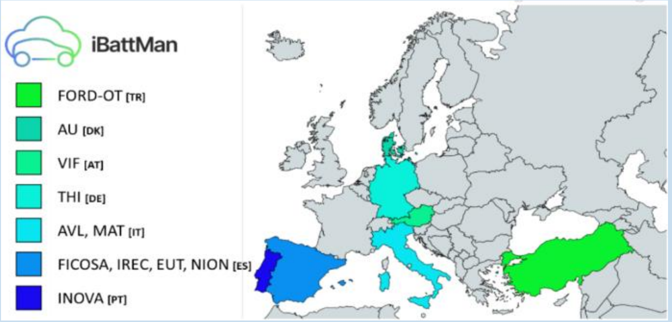


iBattMan

Smart, Connected and Secure Battery Management System Enhanced by Next-Generation Edge- and Cloud-Computing, Sensors and Interoperable Architecture

iBattMan aims to design an **innovative, modular and scalable BMS**, for a wide range of vehicles, from small passenger cars to e-busses and electric trucks, with **improved performance, connectivity, security and reliability** to enhance battery performance and reduce total cost based on f ownership in **EV applications and smart battery use for grid support and in 2nd life applications**, a holistic design of an **interoperable architecture** and supported by a suite of **advanced sensors** and **edge- and cloud-computational resources**.

CAPACITY OF PARTICIPANTS AND CONSORTIUM



Expertise (●=core expertise | ○="non-core" expertise).	AU	THI	FICOSA	VIF	IREC	NION	EUT	AVL	INOVA	FORD-OT	MAT
Battery packs architectures and materials	○	●		●	●		●	●		●	●
Battery systems safety and compliance		●		●	○			●			○
Battery management system (BMS) architecture and HW components design		○	●	○	○		●	○			
Battery management system (BMS) SW components design			●	●	●		○	○			○
SoX modelling / algorithms (constitutive laws)	○	○	●	●	●					○	○
Edge computing (design, implementation)					●	●					
Cloud computing algorithms and services		○			○	●					
Data-driven SoX predictive models / tools (incl. AI, ML, DL, …)		○		●	●					●	○
External devices design, management and connectivity (ECU, charging station, V2X, Fleet, …)		●			○		○			●	○
Cybersecurity for vehicle and BMS components		●		●	○	○					
System integration (process design, implementation)				○			○	●		○	●
Parametric and integrated system testing	○	●		○	○			●		○	○
Vehicle user profile, tools and features definition	○			○				○		●	●
Battery supply chain security	●						○				
Life cycle analysis (LCA), Life cycle cost (LCC)					○						
Project management	●	○		○				●	○		○
Risk monitoring and management								●	●		○
Exploitation and business planning							○	○	●	○	○

Co-funded by the European Union

iBattMan

WP1 – Project Management & Coordination

WP2 – System Requirements

WP3 – BMS Platform development

WP4 – BMS Platform development

WP5 – Applications and Connectivity

WP6 – System Integration and Testing

WP7 – Dissemination, Standardisation & Exploitation

Overall WP2 Objectives

- Use cases detailed definition and system requirements
- Identification of extensive verification methods
- Updated definition of parameters, metrics and targets
- Threat and risk analysis to identify security requirements
- High level tests plan, procedures and harmonised (normalised) validation methodologies
- Standards assessment of communication protocols

Overall WP3 Objectives

- Develop SW and HW architecture of the BMS from system specifications.
- Develop HW according to the proposed sensors.
- Develop security controls for configuration data and authentication.
- CMC to reduce 10% of the battery-pack volume.
- Develop a multi-sensing unit for providing fast and reliable action.

Co-funded by the European Union

Overall WP4 Objectives

- Highly accurate **battery model** with **ageing mechanisms** and **machine-learning** surrogate model
- Reduced order model for **onboard** BMS implementation to enable health-conscious control of battery
- Develop detection of **manipulation**
- **Onboard BMS functions** incl. adaptive battery parameters and fast charging control to extend operating envelope/life
- **Cloud BMS functions** including ageing estimation, health prognostics, and remaining useful life estimation

Co-funded by the European Union

Overall WP5 Objectives

- Enable charging station as battery tester for SoX determination for the user
- Better EOL and aging estimation
- Increase resilience of system for cyberattacks
- Establish lightweight security architecture for a secure BMS
- Realisation of decentralized identity/access management for fine-granular access to BMS relevant data
- BMS connection with bi-directional chargers and applications for smart charging, grid support and 2nd life applications

Overall WP6 Objectives

- BMS Physical integration
- Battery BVT definition and implementation
- Validation plan, test method and execution for SoX assessment

Co-funded by the European Union

iBattMan

Smart, Connected and Secure Battery Management System Enhanced by Next-Generation Edge- and Cloud-Computing, Sensors and Interoperable Architecture

THANK YOU FOR YOUR ATTENTION

Co-funded by the European Union Horizon Europe programme (HORIZON-CL5-2023-D5-01). Under Grant agreement n. 101138856.