



# SEMS'23

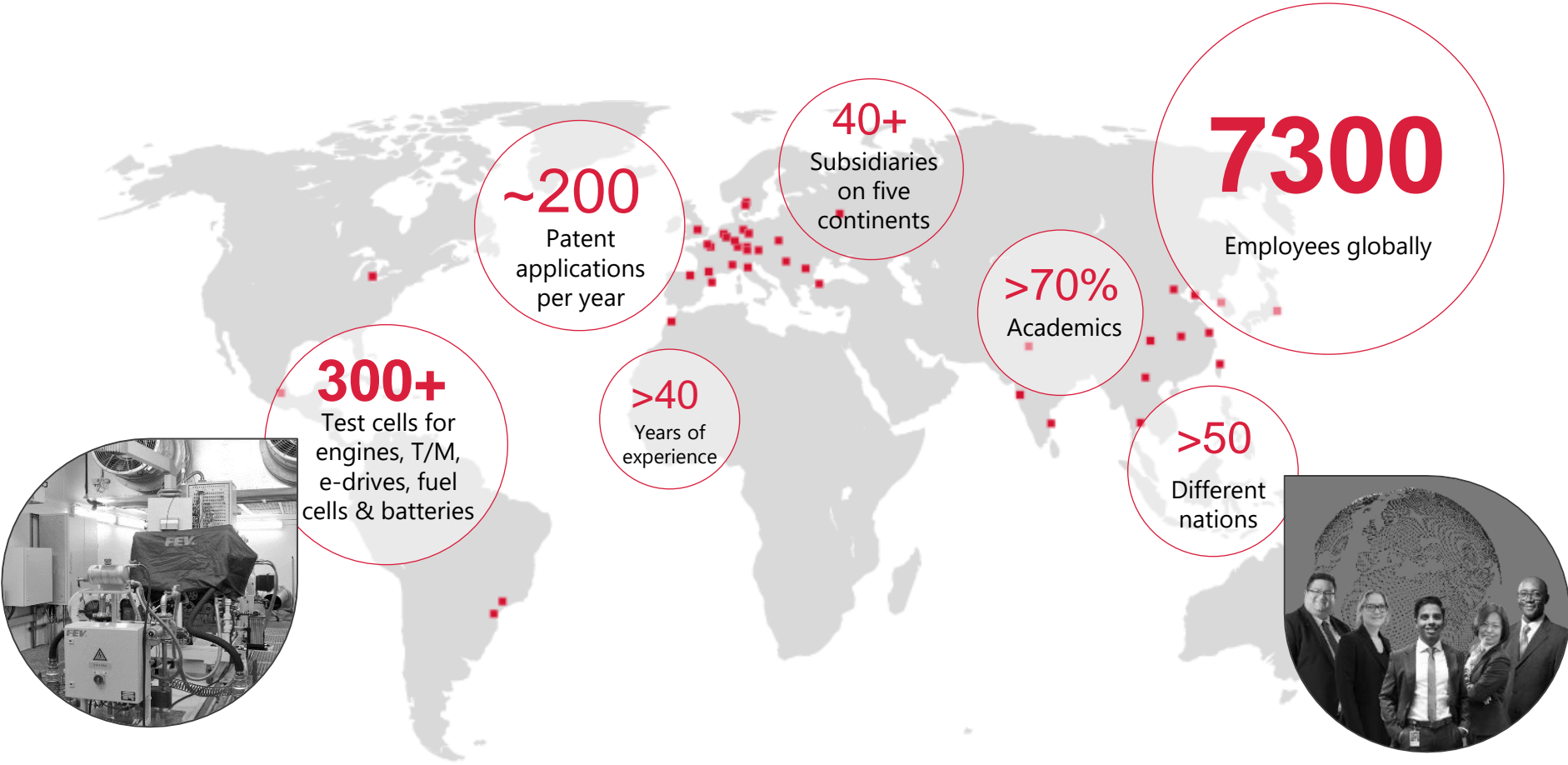
Cloud connected BMS

Zastosowanie chmury obliczeniowej w samochodowym systemie zarządzania baterią

# Your engineering and consulting partner – Strong, competent and reliable



GLOBAL REACH – ONE FACE TO THE CUSTOMER





**FEV**

**130**

Employees



**TISAX**

Focus on  
information  
security

**Automotive**

Familiar with OEMs and  
Tier1s' working style

**Kraków**

City of Science  
and Technology

Main office

**Poznań**

Branch office

**2003**

18 years of  
experience

**1,5k m<sup>2</sup>**

Comfortable  
office space

**ISO  
9001:2015**

Process awareness  
supports quality

**FEV POLSKA**

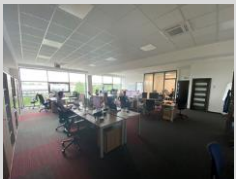
# FEV Polska Sp z o.o. – Engineering Center

## SERVICES



- Powertrain Development
  - Testing
  - Intelligent Mobility & Software Engineering
- 
- ADAS/AD competence center
    - XiL Testing & Vehicle Validation
    - Software and Hardware Integration
    - Software: Algorithms, Computer Vision / AI-ML, Sensor Fusion,
  - Cyber Security competence center
  - **BMS Software development**
  - Powertrain design and simulation:
    - Conventional, hybrid e-powertrain and battery
  - Facility Development & Maintenance Support for test benches:
    - Powertrain, E-mobility, chassis dyno and components

## FACILITIES

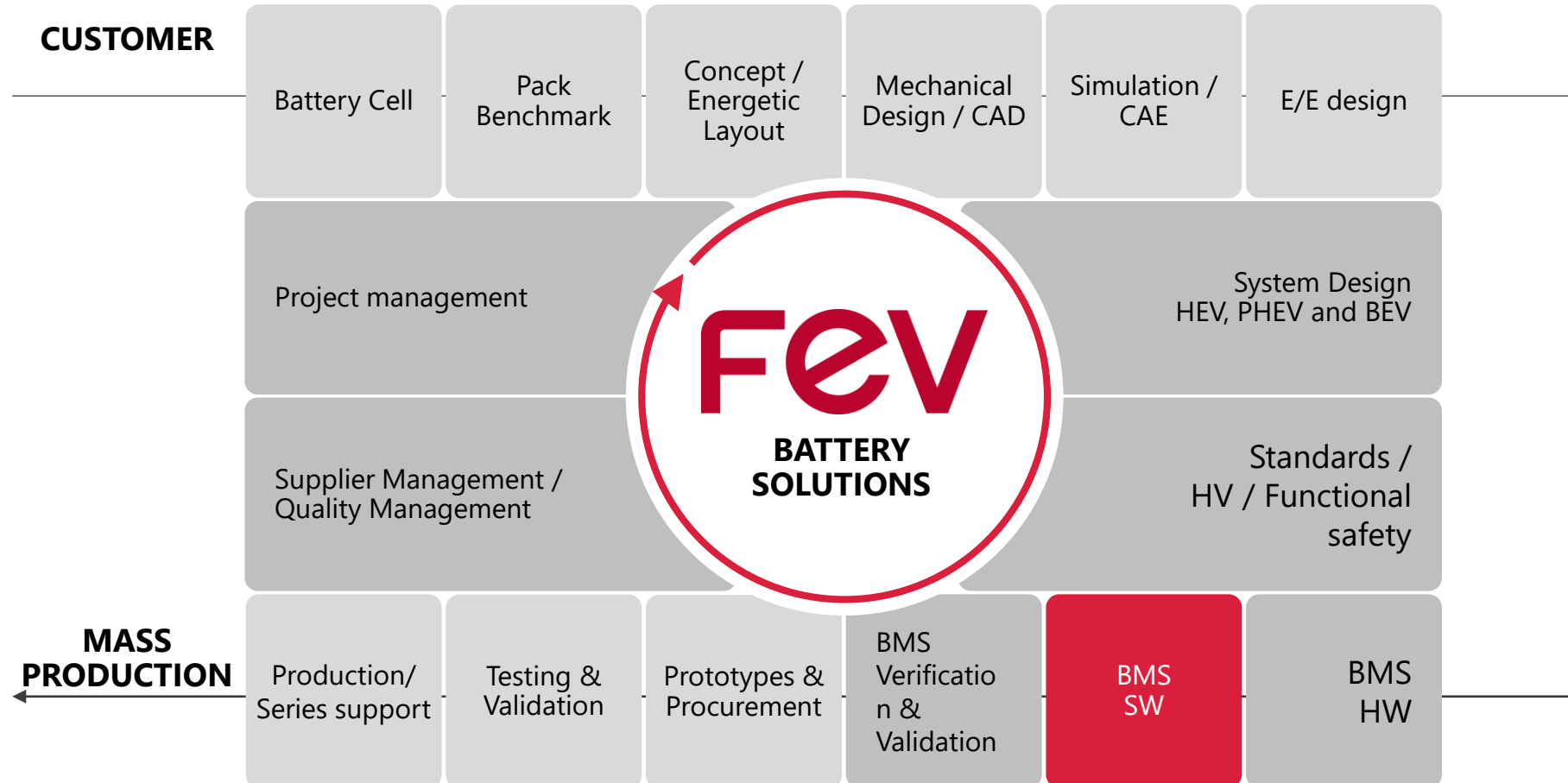


- Locations: Krakow, Poznan
  - 130+ engineers
  - Workshop for vehicles and test bench components
  - Laboratory for ADAS testing
  - TISAX approval
- 
- Assembly of test bench equipment
  - Parts procurement & quality assurance
  - Machining workshop
  - ADAS HIL benches
  - 2x Smart Vehicles equipped with ADAS features

# Your global engineering partner ...our services for customized battery solutions



FEV 'S PORTOFOLIO OF SERVICES SUPPORTING CUSTOMERS FROM CONCEPT TILL SOP



# FEV Battery management systems (BMS) highlights

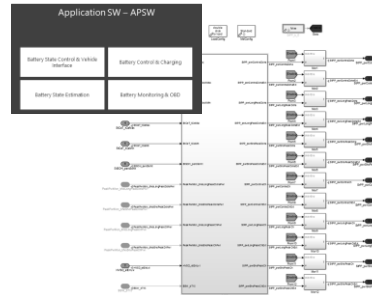


## BATTERY MANAGEMENT SYSTEM SOFTWARE DEVELOPMENT

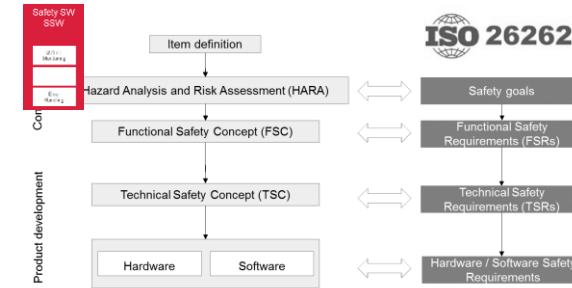
### Requirements & SW Specification



### Application-SW Development



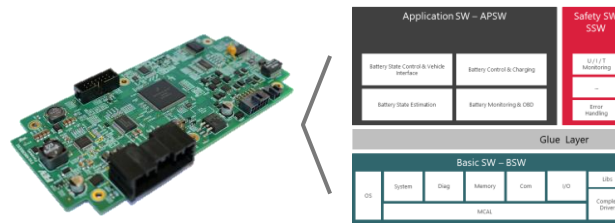
### Level 2 Safety-SW Development



### Battery & Vehicle Calibration



### SW Integration



### Basic-SW Development

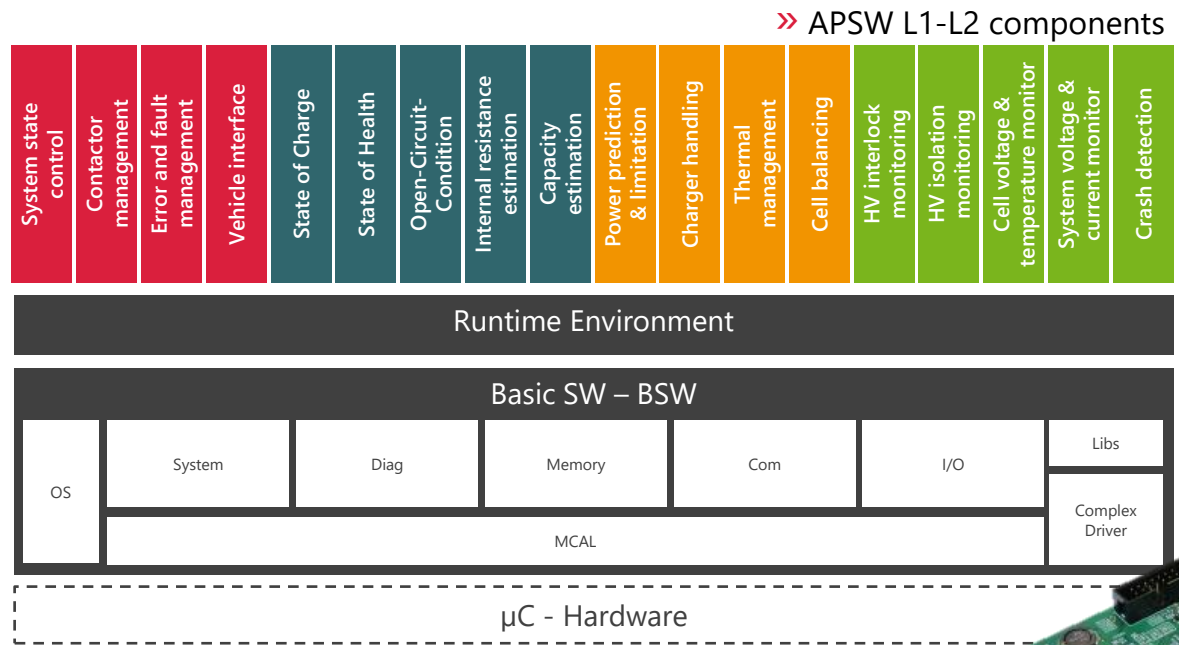
```

Basic SW - BSW
-----
| OS | System | Diag | Memory | Can | ID | Lib |
|----|-----|-----|-----|----|---|----|
| MCAL |         |         |         |    |   |    |

//The error sources
12 #define CAN_B_RxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
13 #define CAN_B_TxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
14 #define CAN_Diag_D_RxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
15 #define CAN_Diag_D_TxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
16 #define CAN_Diag_M_RxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
17 #define CAN_Diag_M_TxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
18 #define CAN_Diag_P_RxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
19 #define CAN_Diag_P_TxErrCnt 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 255 */
20 //These defines are not used in the original software.
21 #define CAN_VehCrashDetected 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 1 */
22 #define CAN_BMS_Bzr10 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 1 */
23 #define CAN_BMS_Bzr10 0 /* LSB: 2^0 OFF: 0 MIN/MAX: 0 .. 1 */
24
25 CAN_SWCb: messageData:
26 CAN_SWCb: messageData_02;
27
28 unsigned int VCU_BCU_Control_ctRoll_old = 0;
29
30 CAN_SWCb: messageData_Gateway:
31 unsigned char vcuDocMsg1[];
32 unsigned char vcuDocMsg2[];
33 unsigned char bom_Status[];
34 unsigned char STATUS_SDM[];
    
```

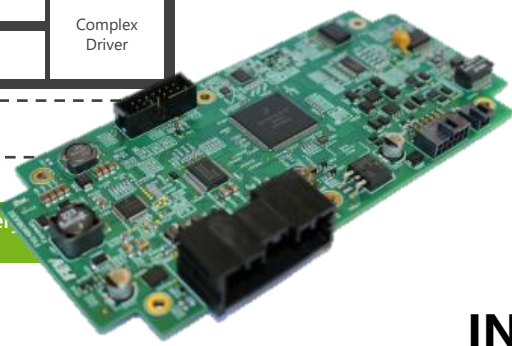
# FEV Battery management systems (BMS) highlights

FEV CAN DELIVER COMPLETE BMS SOFTWARE



**LEGEND:**

- Battery State Control & Vehicle Interface
- Battery State Estimation
- Battery Control & Charging
- Batter...



**8 (EIGHT)**  
**SERIES PROJECTS**  
 WITH FEV BMS SW SINCE 2014

**WHITE BOX**  
**BMS SW AND HW**  
 AVAILABLE AS LICENSE

**Advanced SoX**  
**PATENTED FUNCTIONS**  
 AVAILABLE AS LICENSE



**IN-HOUSE TOOLCHAIN**  
 FOR FAST AND RELIABLE SOFTWARE

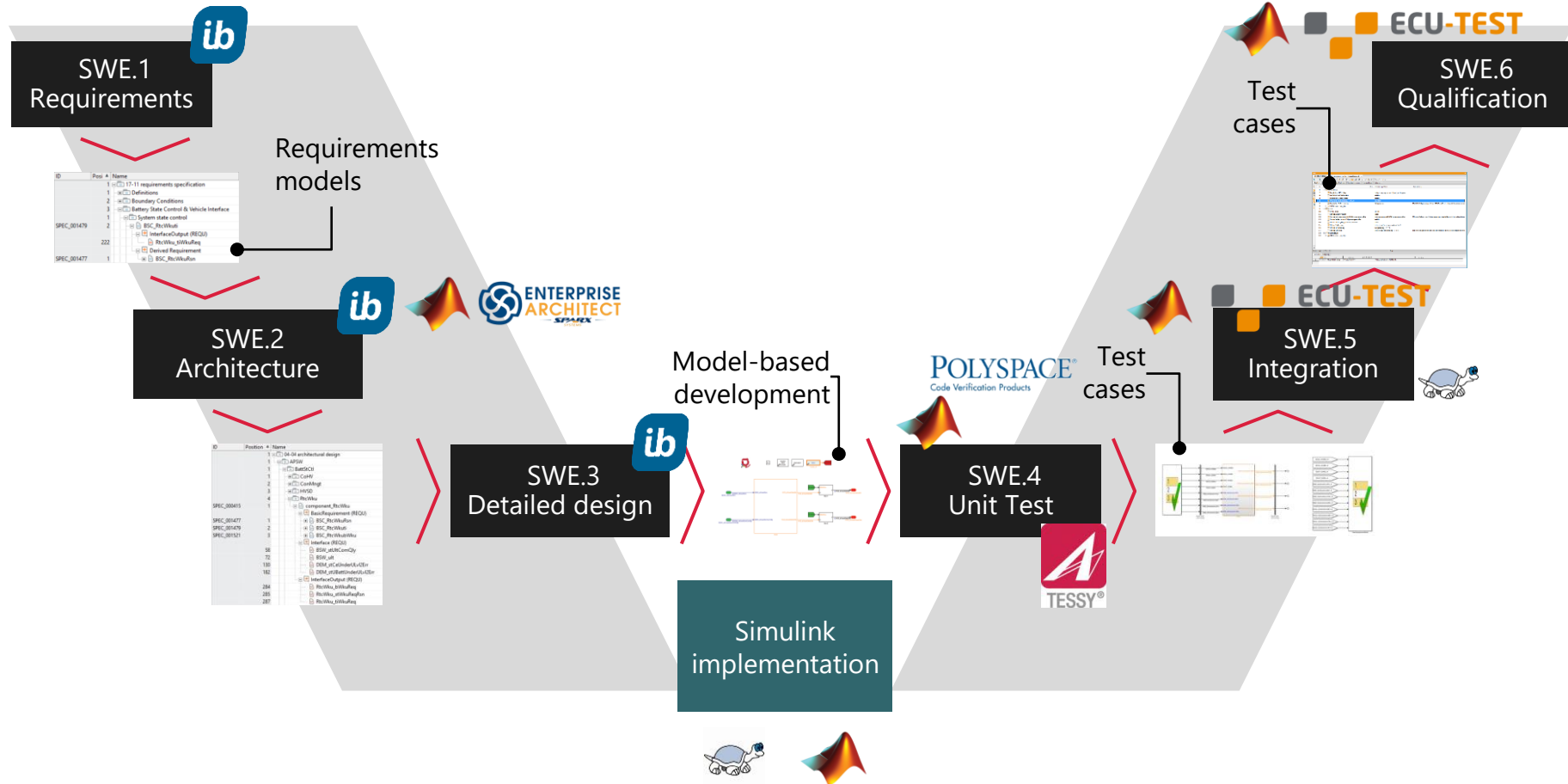
<sup>1</sup>QM: Quality Management → representing application with no automotive hazards and, therefore, no safety requirements to manage under the [ISO 26262](#) safety processes

# FEV Battery management systems (BMS) highlights



FEV'S TOOLCHAIN SUPPORT IN PROVIDING CONSISTENCY BETWEEN THE TOOLS

» CASE EXAMPLE



Based on the project specific requirements an individual composition of tools will be used



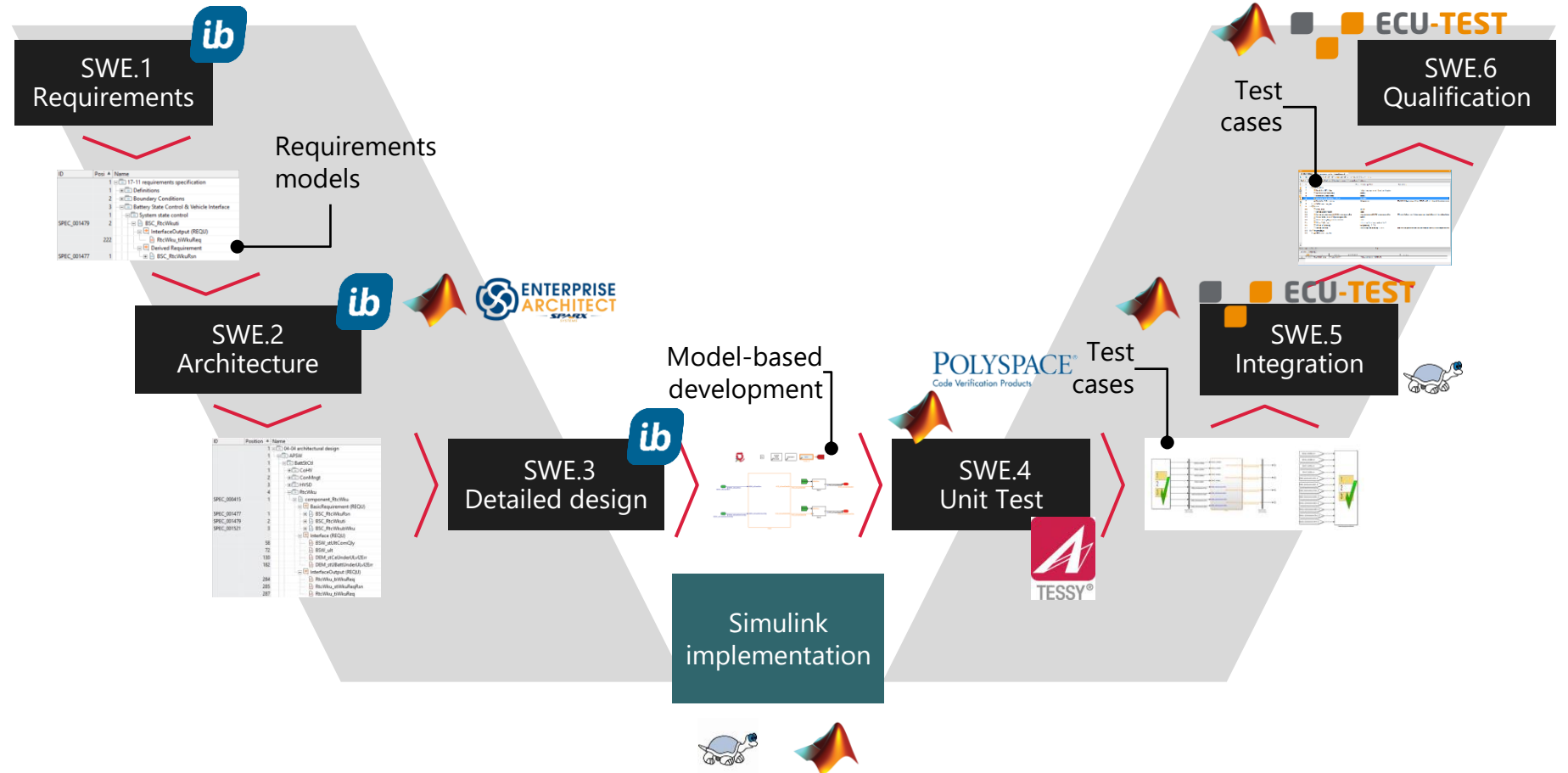
# FEV Battery management systems (BMS) highlights



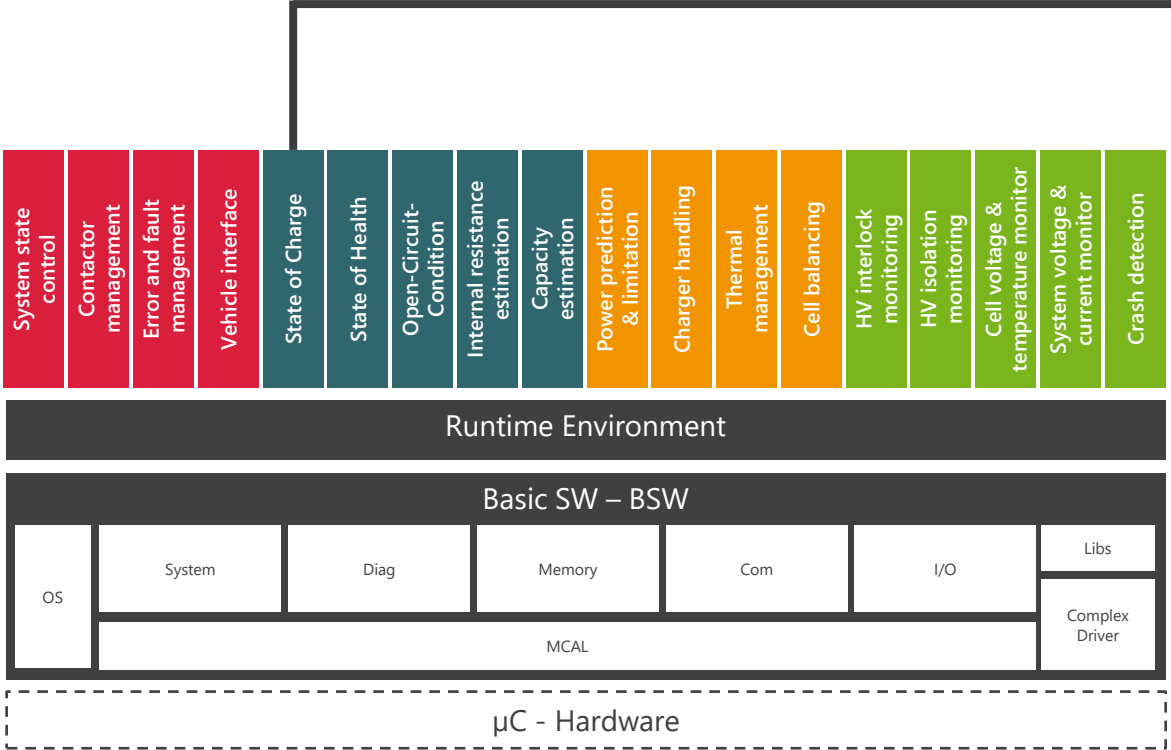
FEV'S TOOLCHAIN SUPPORT IN PROVIDING CONSISTENCY BETWEEN THE TOOLS

>> CASE EXAMPLE

- MATLAB
- AUTOSAR Blockset
- Simulink
- Simulink Requirements
- FEV FD Library for Simulink
- FEV FD SDD
- Stateflow
- Embedded Coder
- MATLAB Coder
- Simulink Coder
- Simulink Check
- Simulink Coverage
- Simulink Test

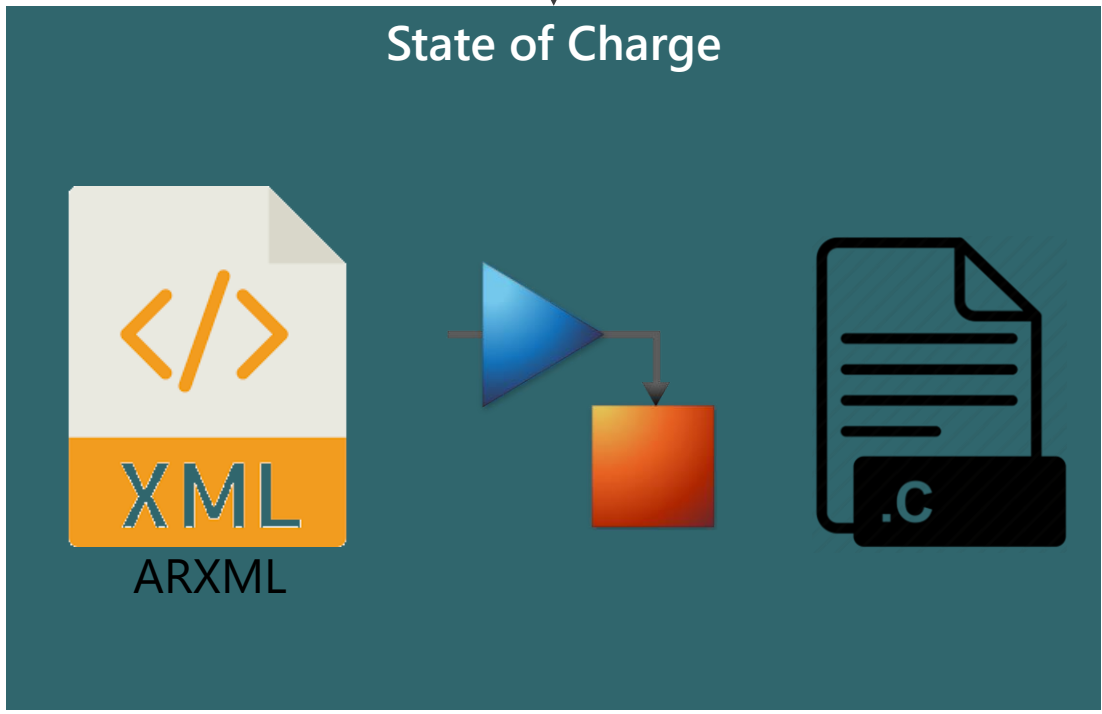


# APSW Component definition



**LEGEND:**

Battery State Control & Vehicle Interface	Battery State Estimation	Battery Control & Charging	Battery Monitoring & OBD
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# FEV Battery management systems (BMS) highlights

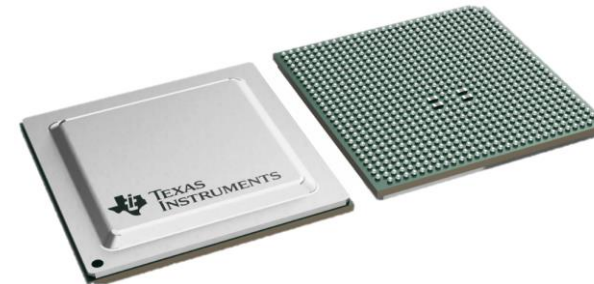
## Reference project: Cloud connected battery systems



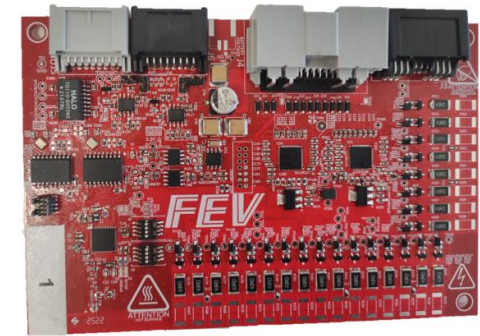
EU FUNDED H2020 PROJECT

DEVELOPMENT OF A NOVEL BMS

- FEV develops a novel BMS HW & SW including beyond state of art SOx algorithms with AI and remote functions.
- Highlights
  - **High voltage BMS HW for 1000V:**
    - System on chip-based design
    - **Wireless** master-slave communication
    - On-board electrochemical impedance spectroscopy (EIS) measurement
  - **Advanced SOx Algorithms:**
    - **Anode controlled charge (ACC)** algorithm to reduce charging time
    - Cloud based Kalman-filtered state of health (SOH)
    - **High accuracy** with Kalman-filtered **state of charge (SOC)**
    - Thermal prediction algorithm for **energy optimization**
  - **Cloud Systems:**
    - Big data transmission and storage on the cloud
    - Transmission method of large files through CAN

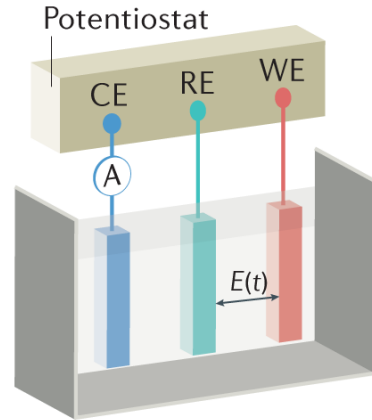


Automotive Grade System on Chip

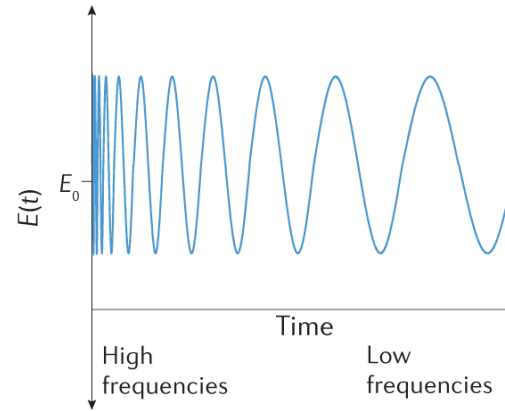


# Electrochemical impedance spectroscopy (EIS) measurement

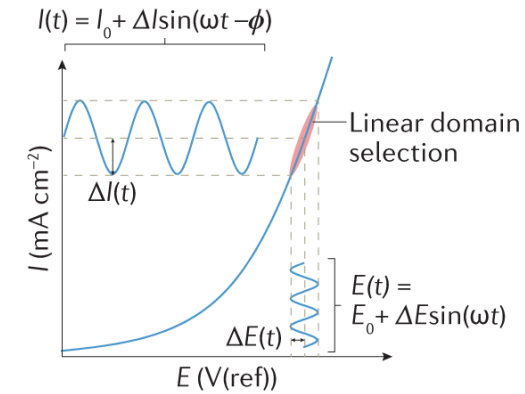
**a Electrochemical system**



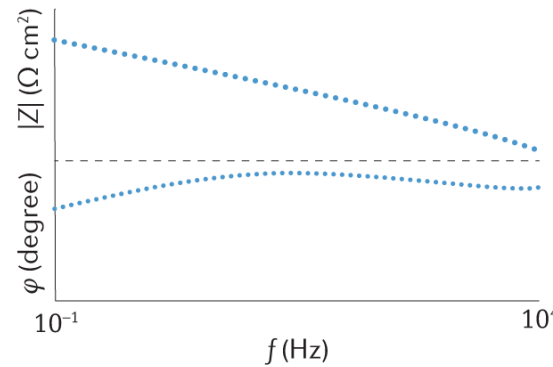
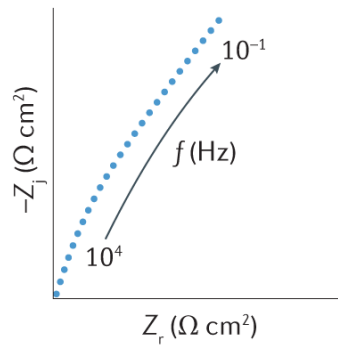
**b Perturbation signal**



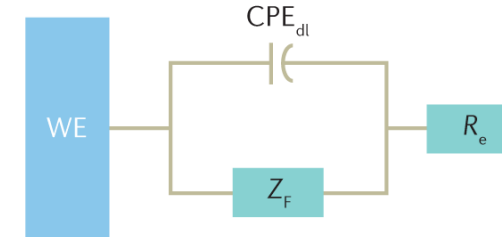
**c Electrochemical response**



**d Graphical representation**



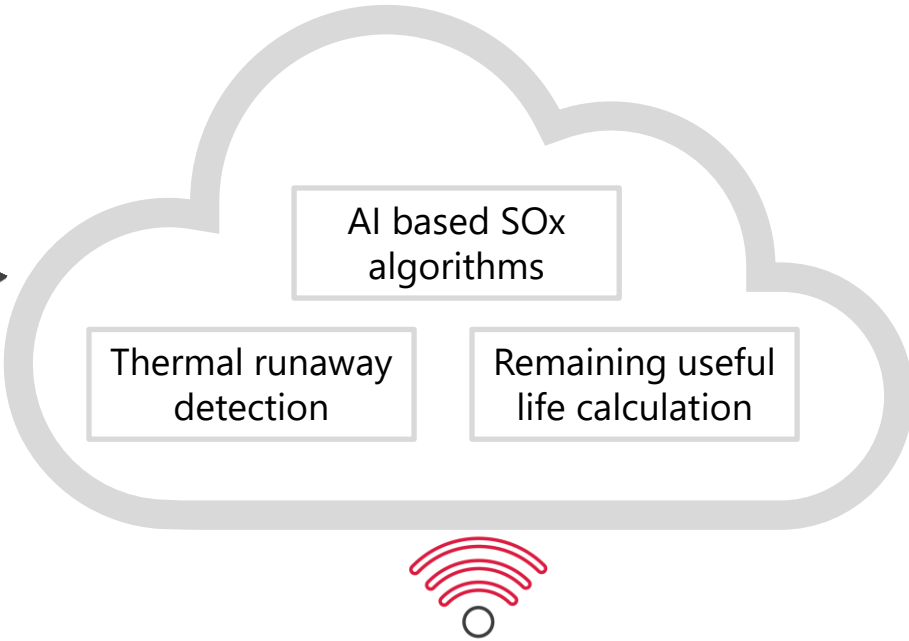
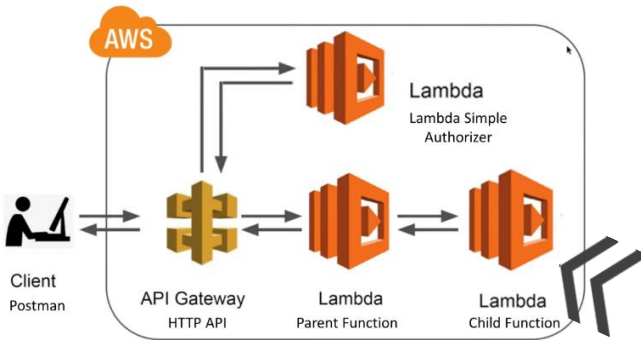
**e Equivalent circuit and model**



$$Z_{\text{tot}}(\omega) = R_e + \frac{Z_F}{1 + Z_F(j\omega)^\alpha Q}$$

Source: Wang, S., Zhang, J., Gharbi, O. *et al.* **Electrochemical impedance spectroscopy**. *Nat Rev Methods Primers* **1**, 41 (2021). <https://doi.org/10.1038/s43586-021-00039-w>

# Cloud connected BMS



- **SOH**
- **AI models**
- **RUL**

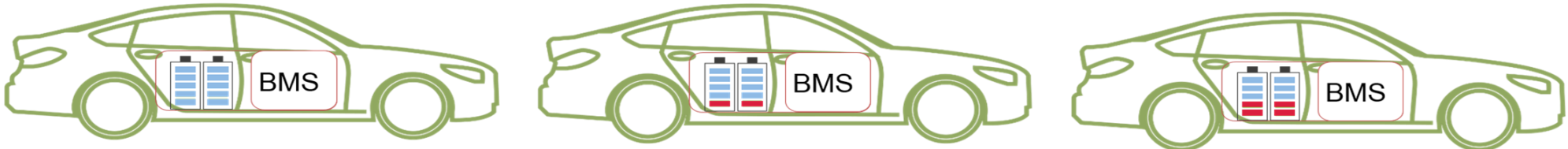
- **Voltages:** Serial voltages & Main voltage
- **Current**
- **Temperature** values

- **SoC** values
- **Charging/Discharging current**
- **Cycle counter**

- **Contactor status**
- **Battery model parameters:** ECM parameters
- **Electrochemical Impedance spectroscopy** measurement results

# SOH Algorithm and Validation

## STATE OF HEALTH DESCRIPTION

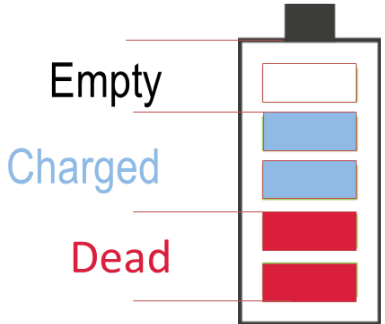


$$SOH = 1 - (A_{cal} + A_{cyc})$$



$$SOH_{Ri} = 1 - \frac{R(t) - R(t_0)}{R(t_0)}$$

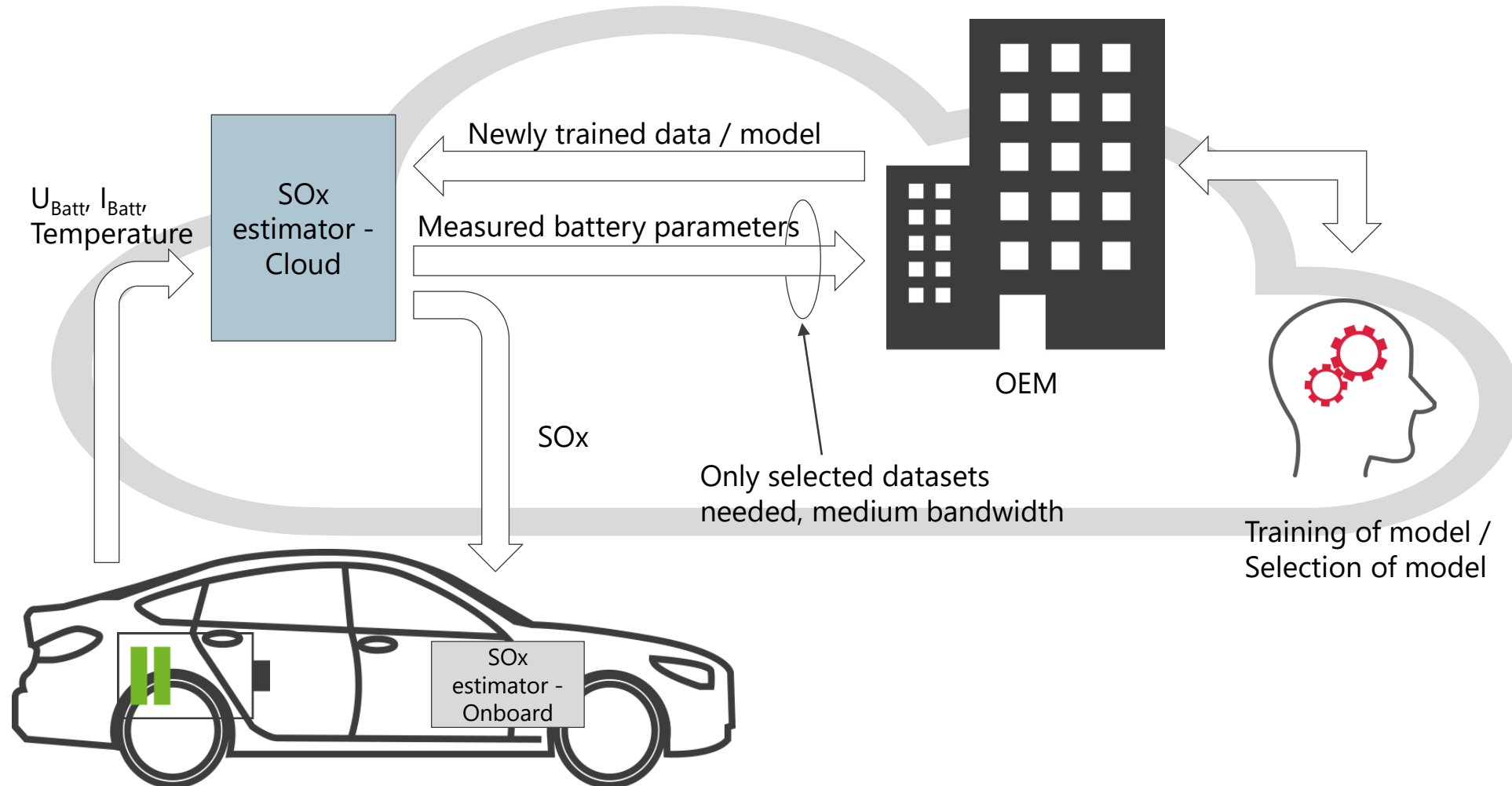
$$SOH_{Cp} = 1 - \frac{C(t_0) - C(t)}{C(t_0)}$$



# Cloud connected BMS



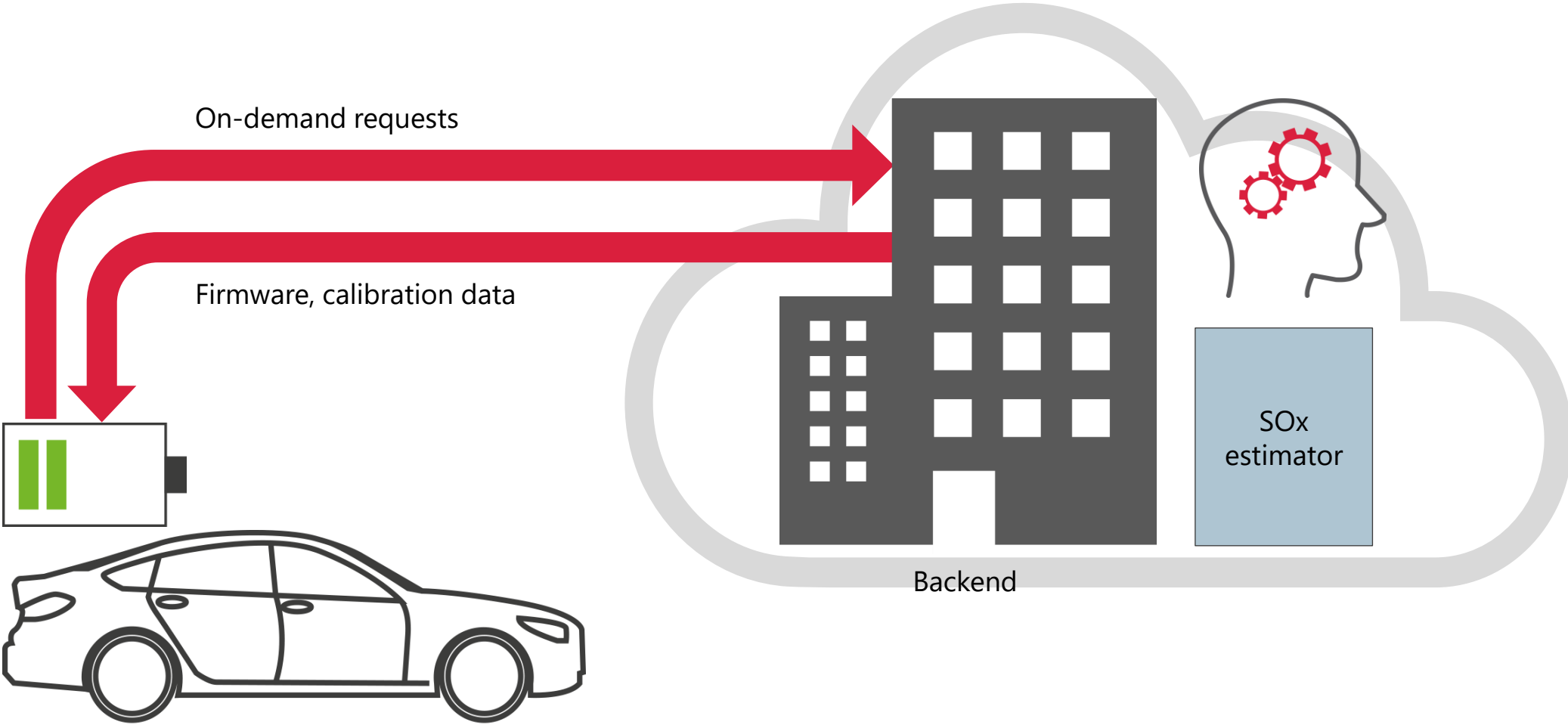
## HYBRID APPROACH: SOX ESTIMATOR ON CLOUD & VEHICLE



# Cloud connected BMS



BACKING MAXIMUM BMS EFFICIENCY





# Cloud connected BMS

## COMPARISON OF ONBOARD AND OFFBOARD COMPUTING



### On-board computing

#### ■ Advantages

- Results are available almost immediately (short delay because of processing time)
- Can be displayed to the driver
- Decisions can be taken (by driver or by algorithm) immediately

#### ■ Disadvantages

- Low processing power
- Only mini-batch processing possible
- Only causal processing possible



Usage of AI accelerator microprocessor



### Off-board computing

#### ■ Advantages

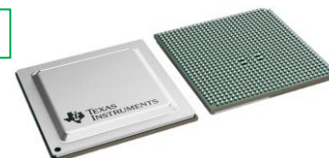
- Very large computational power (distributed computing resources, cloud computing)
- Processing of full datasets
- Expert input possible

#### ■ Disadvantages

- Not available to the driver immediately (even with radio/mobile service there will be a delay possible problems with availability of service)
- Transfer of high bandwidth data necessary (has to be stored in the car and read out in the car shop)

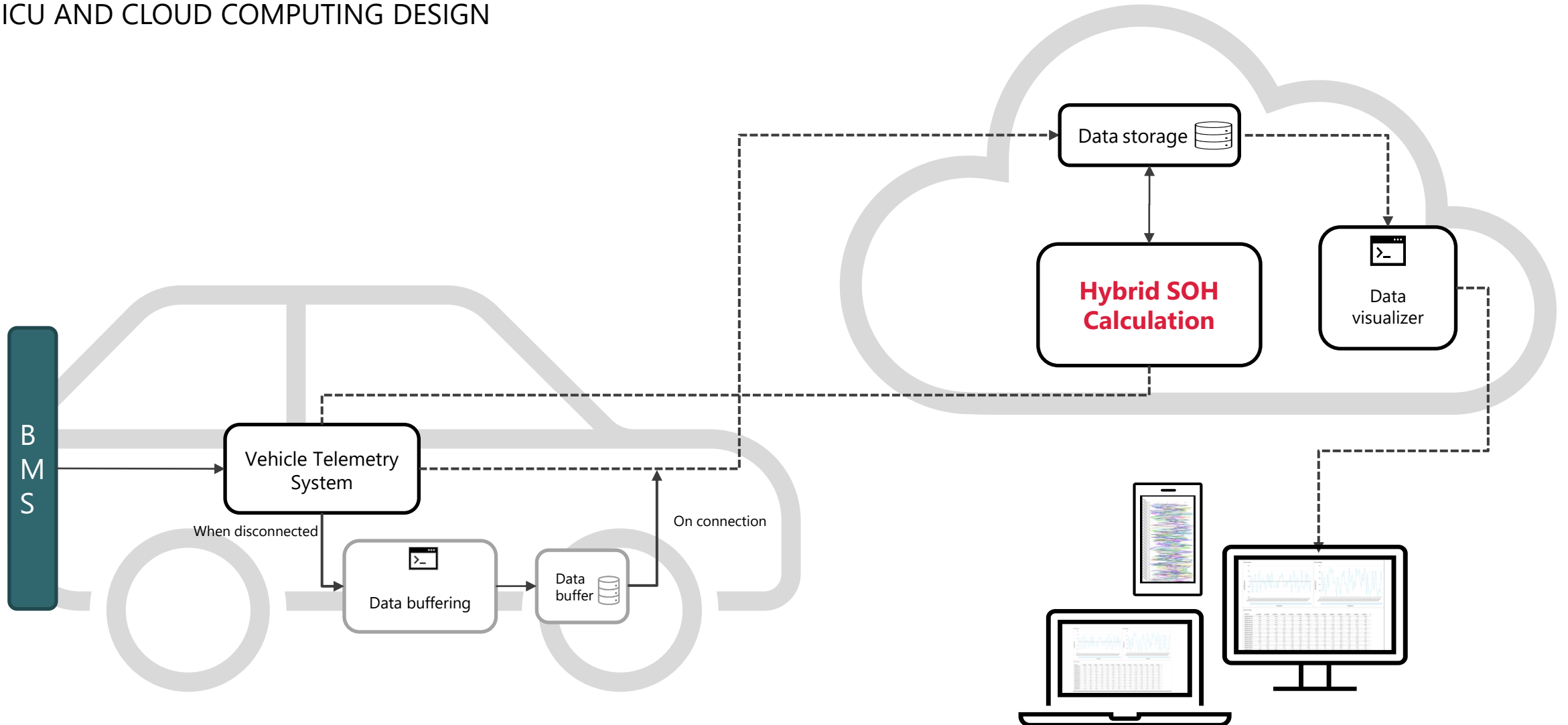
Hybrid method

Reduced bandwidth due to preprocessing



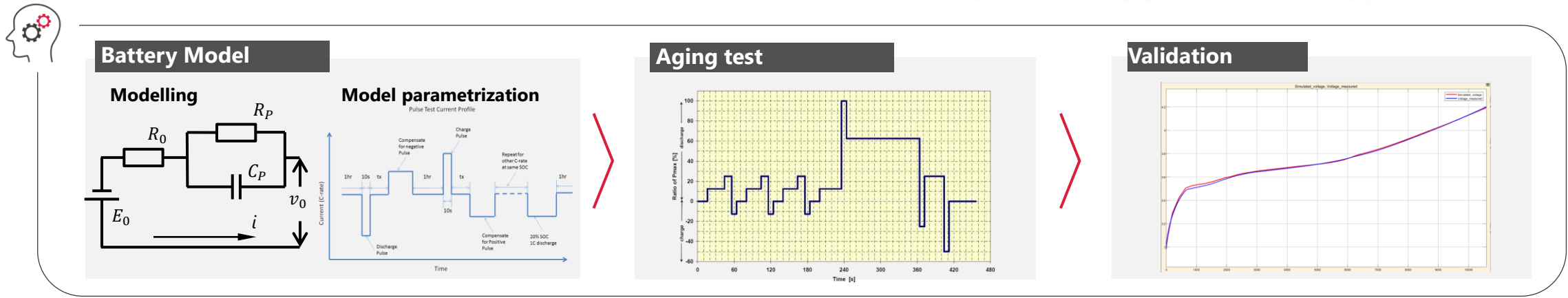
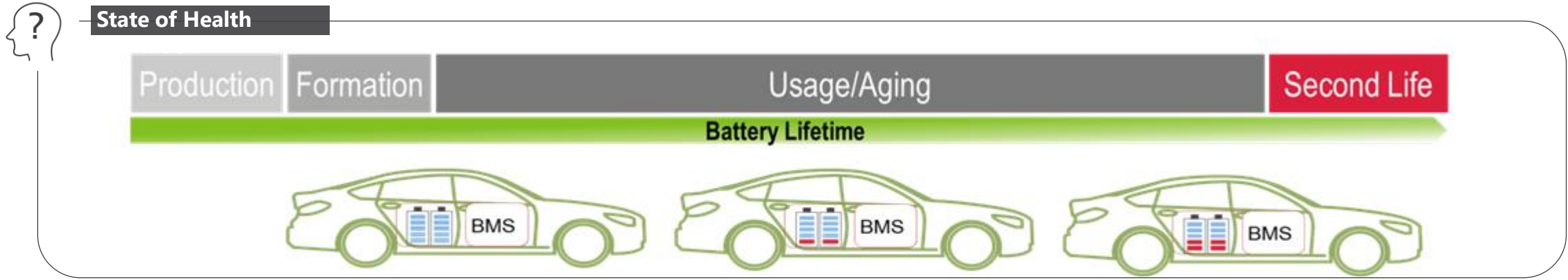
# SOH Algorithm and Validation

## ICU AND CLOUD COMPUTING DESIGN



\*Hybrid model in cloud is based on AI/ML and battery model.

# SOH Algorithm and Validation



## Contact Details



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## Q&A

Thank you for your attention.

feel evolution