Battery management by multi-domain digital twins

The BATMAX project

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Objectives of BATMAX
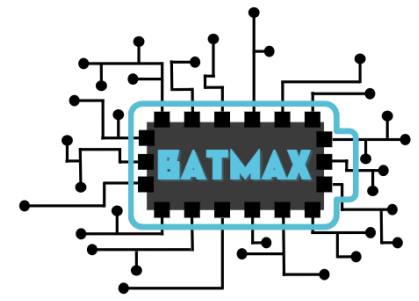
- **The main objective** is to contribute to improving battery system performance, safety, reliability, service life, lifetime cost, and integrating different use applications

- In addition, BATMAX is aiming to
  - develop **framework** for efficient parametrization of physics-based models
  - develop **hardware and sensorisation** on cell and system level for collection and communication of battery measurement data
  - create **hybrid and AI-driven models** to optimise lifetime and management of the battery (BMS)
  - develop **adaptable battery management** with multi-scale battery digital twin framework for dynamic operation

The conceptual approach of BATMAX
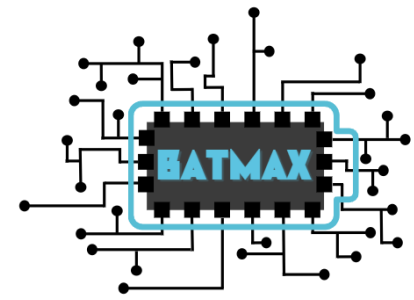
Efficient Parameterization

Living Parameter Database
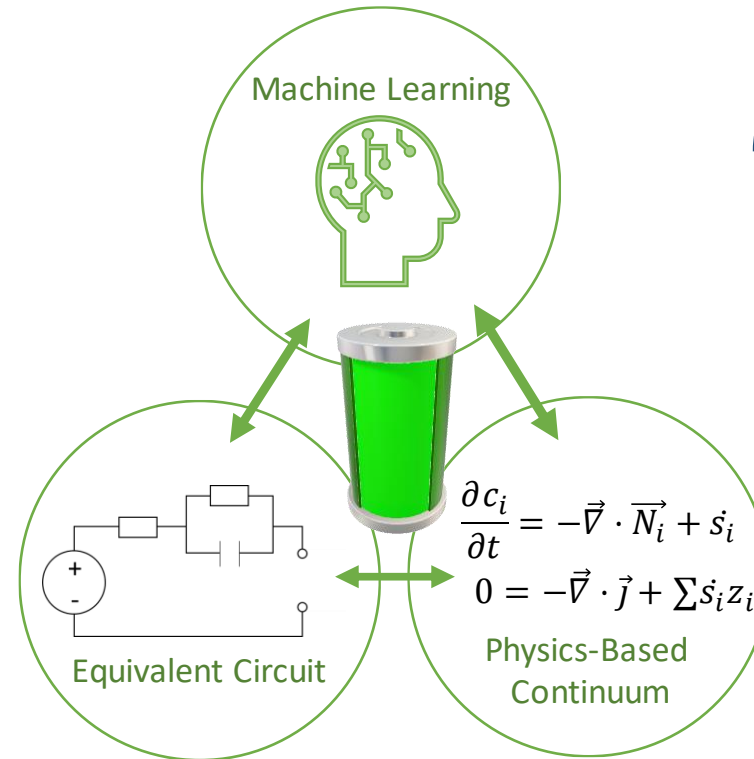
Non-Destructive Parameterization

Microscopy and Ex-situ Parameterization

Experimental battery data from laboratory

Digital Twin of Batteries

Machine Learning

Equivalent Circuit

Physics-Based Continuum

$$\frac{\partial c_i}{\partial t} = -\vec{\nabla} \cdot \overrightarrow{N_i} + \dot{s}_i$$

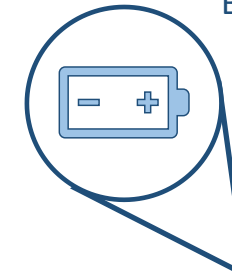$$0 = -\vec{\nabla} \cdot \vec{j} + \sum \dot{s}_i z_i$$

Real-Time Flow of Field Data

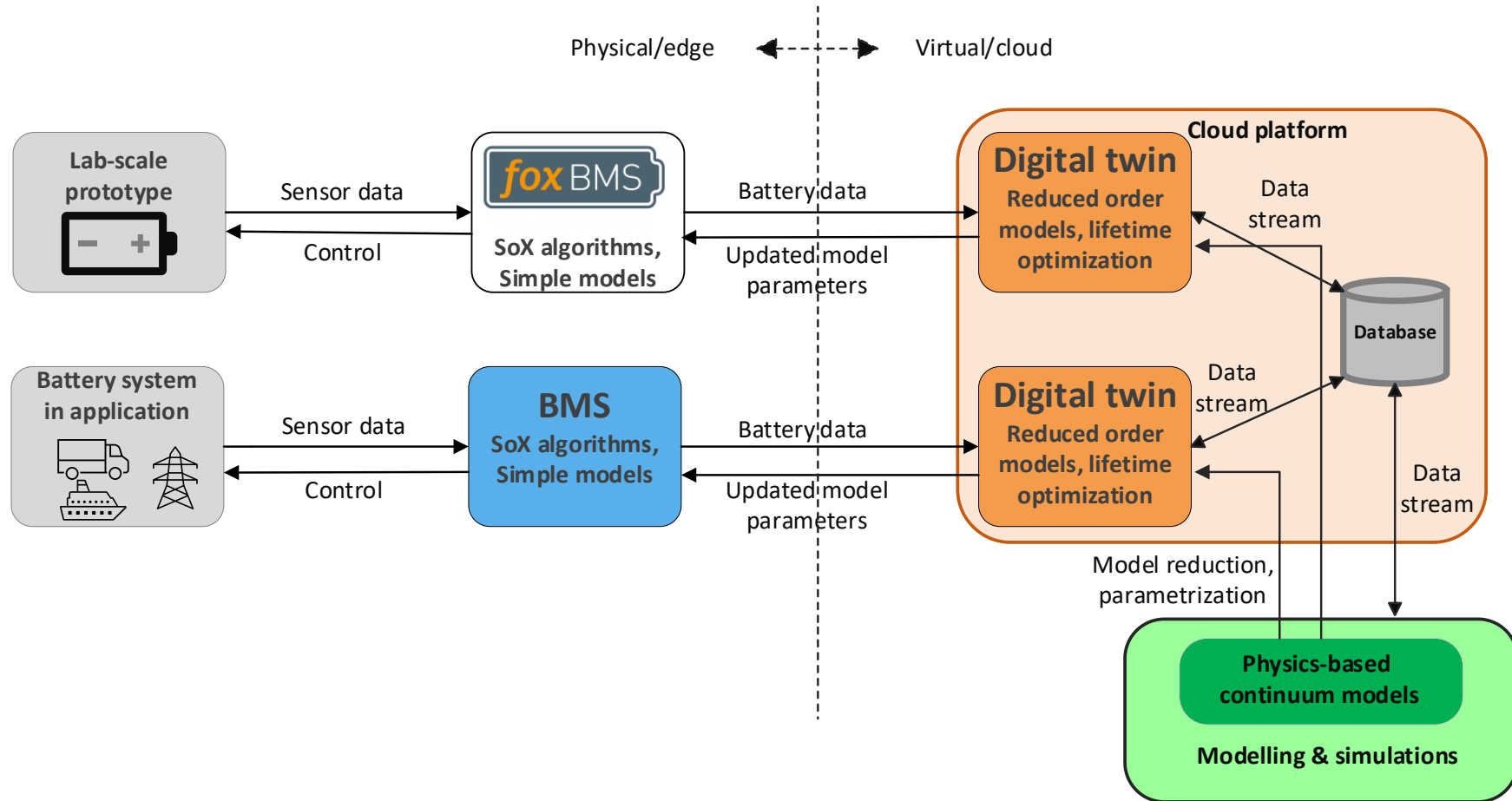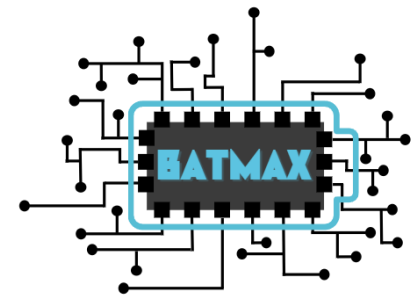Internet of Things, cloud connectivity with API
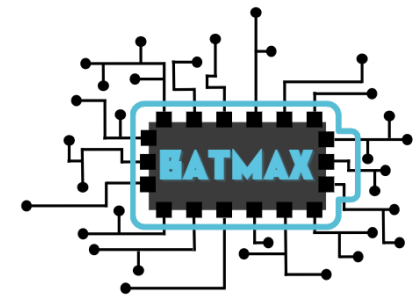
Smart Sensing Battery Management

Electric mobility and transport electrification on-road/marine/off-road/stationary

# Data flow between the physical battery system and the cloud platform

Physics-based multi scale modelling

- The physics-based multi-scale modelling activities will build on an existing framework developed at SINTEF, **the Battery Modelling Toolbox (BattMo)**
  - BattMo is an open-source tool and a flexible continuum modelling framework for simulating the performance of electrochemical cells

Parameters for PxD model

| Electrode Parameters		Density g/cm3	Surface area m²/g
Positive electrode	Active material	3.6	6.4
	Binder	1.78	3.76
	Conductive additive	1.6	62
Negative electrode	Active material	2.2	1.33
	Binder 1	1.6	12.1
	Binder 2	1.5	2.24
	Conductive additive	1.6	62

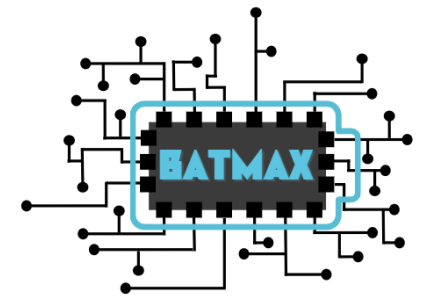Concentration at the surface of active particles during the discharging process (output of P4D model)
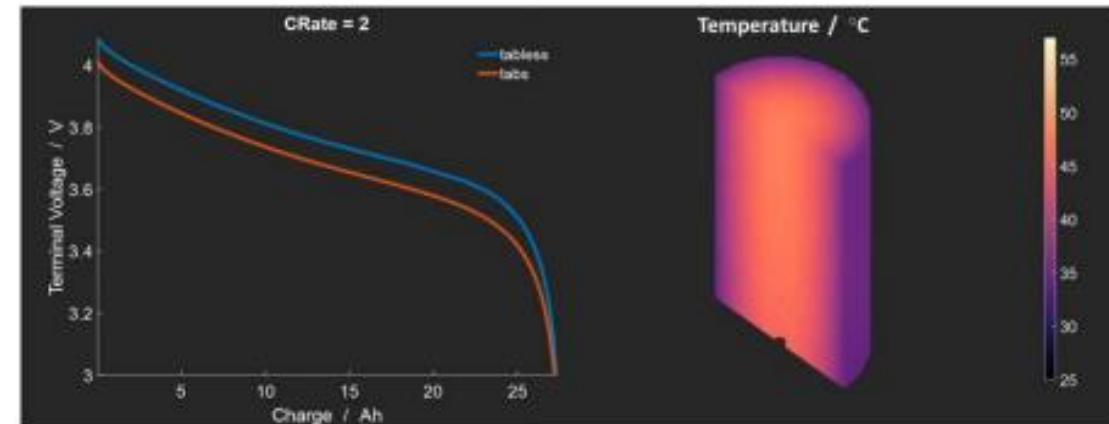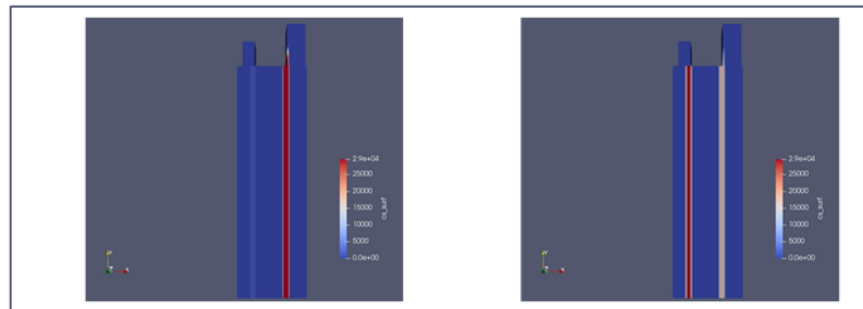
# BMS, sensorisation and battery data collection
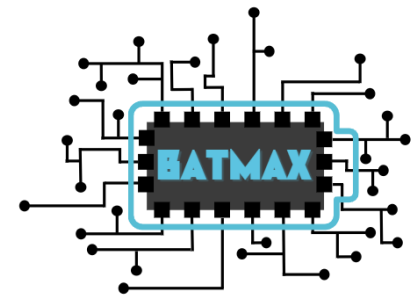
- The BATMAX prototype system will include a 48V battery module with sensors transmitting data to the BMS-Master
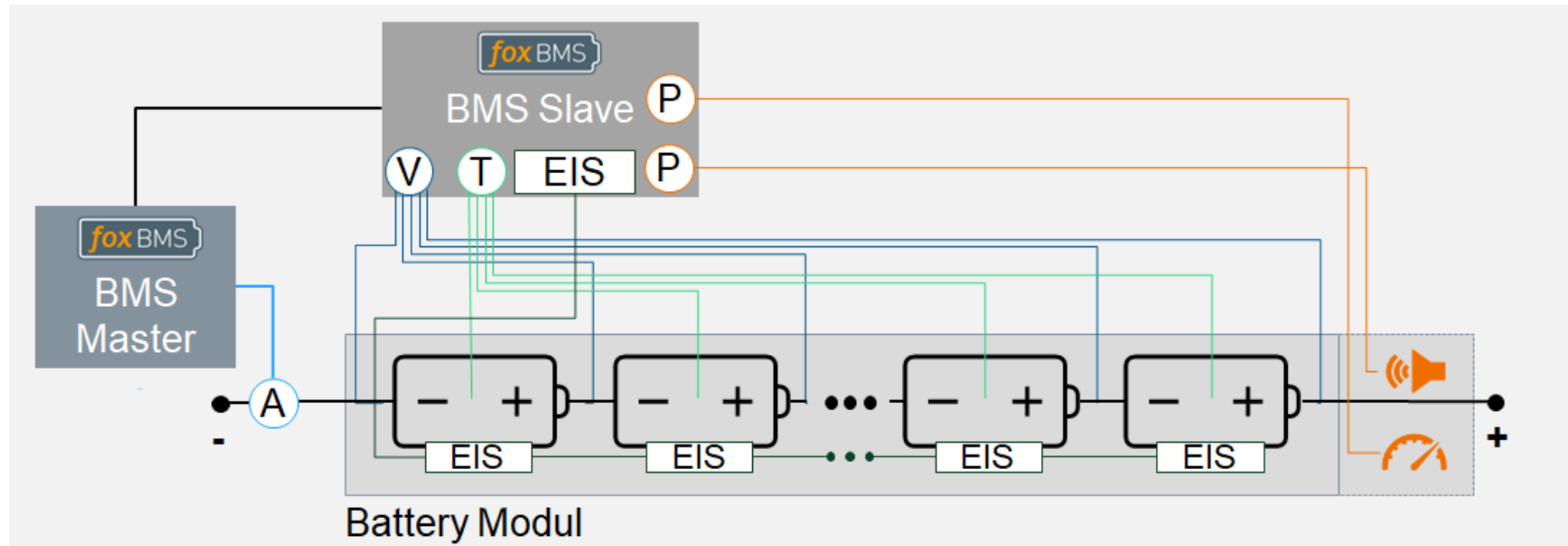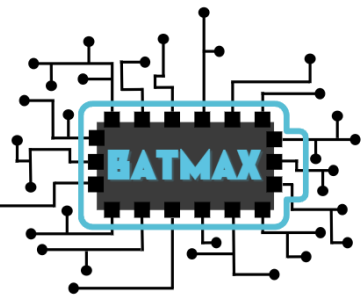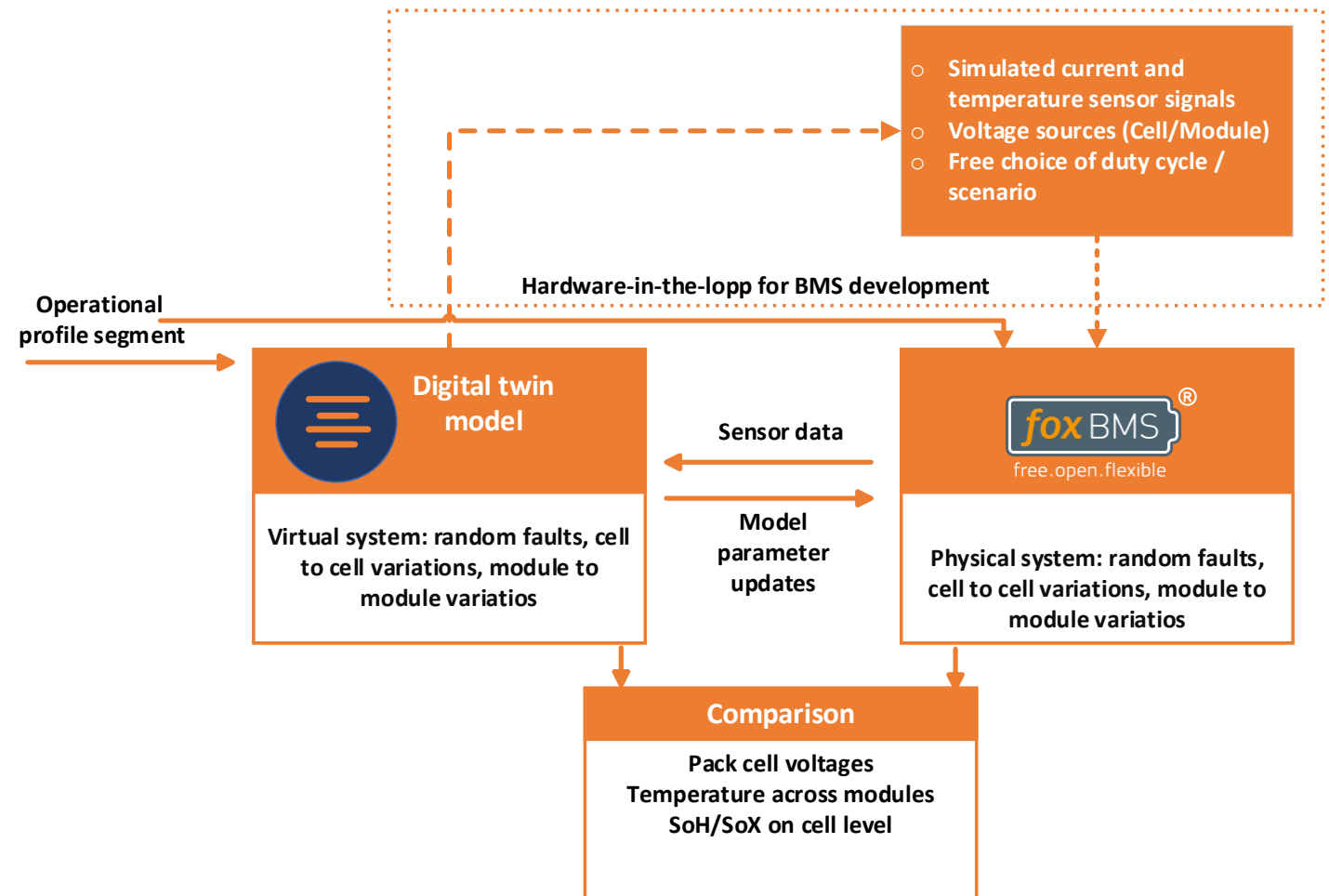
Data, analytics and AI

- The activities on physics-based modelling are complemented by the development of data-driven algorithms and AI

- Heavy use on meaningful data, e.g., from simulation, modelling, and experiments
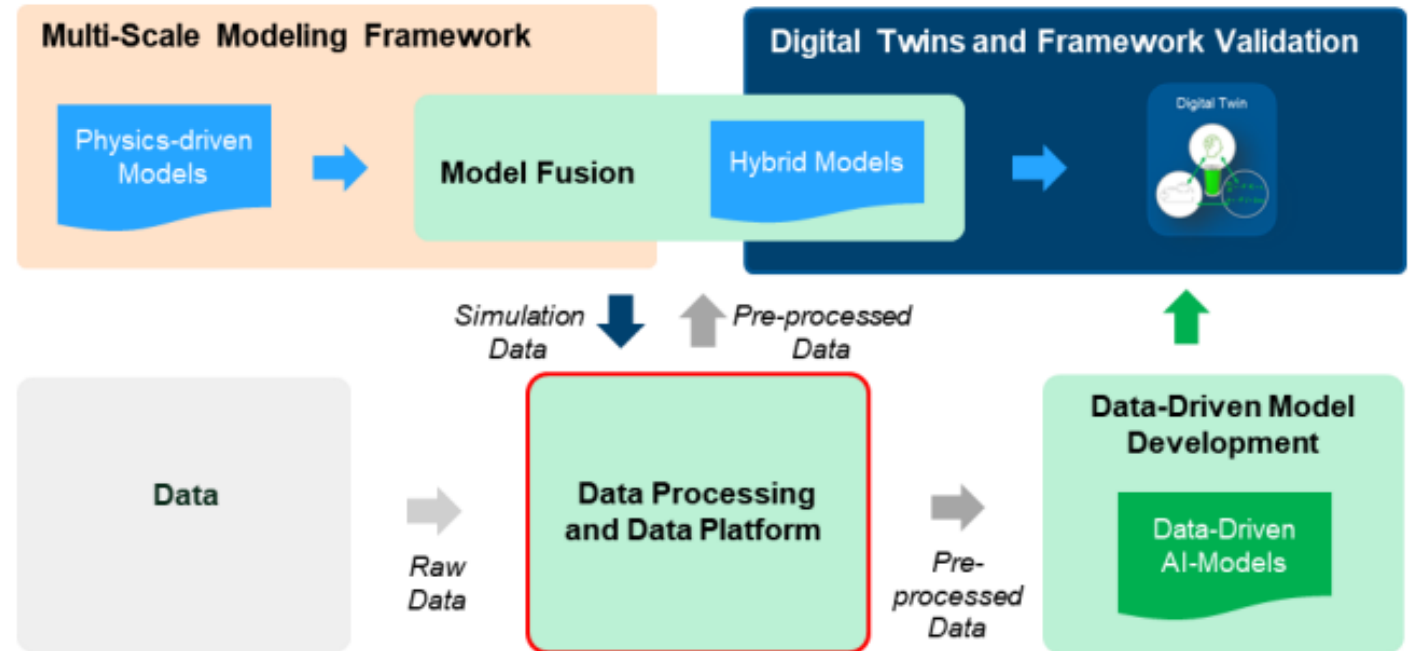
Utilisation of digital twins for optimal battery management

- The digital twin running on a cloud platform will enable
  - **utilisation of more complex battery models**
  - an arrangement for **Hardware in the loop (HIL)**, and
  - research on several **abnormal situations and fault states**, including also safety-critical operation domains

o **Simulated current and temperature sensor signals**
o **Voltage sources (Cell/Module)**
o **Free choice of duty cycle / scenario**

Hardware-in-the-lopp for BMS development

Operational profile segment

Digital twin model

Virtual system: random faults, cell to cell variations, module to module variatios

Sensor data

Model parameter updates

fox BMS®
free.open.flexible

Physical system: random faults, cell to cell variations, module to module variatios

Comparison

Pack cell voltages
Temperature across modules
SoH/SoX on cell level

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Thank you for your attention.

Find out more about BATMAX:
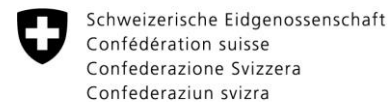Twitter: @batmaxprojecteu
Linkedin: BATMAX project