OBELICS

Optimization of scala**B**le r**E**altime mode**L**s
and funct**I**onal testing for e-drive **C**oncept**S**

Horst Pfluegl et al.

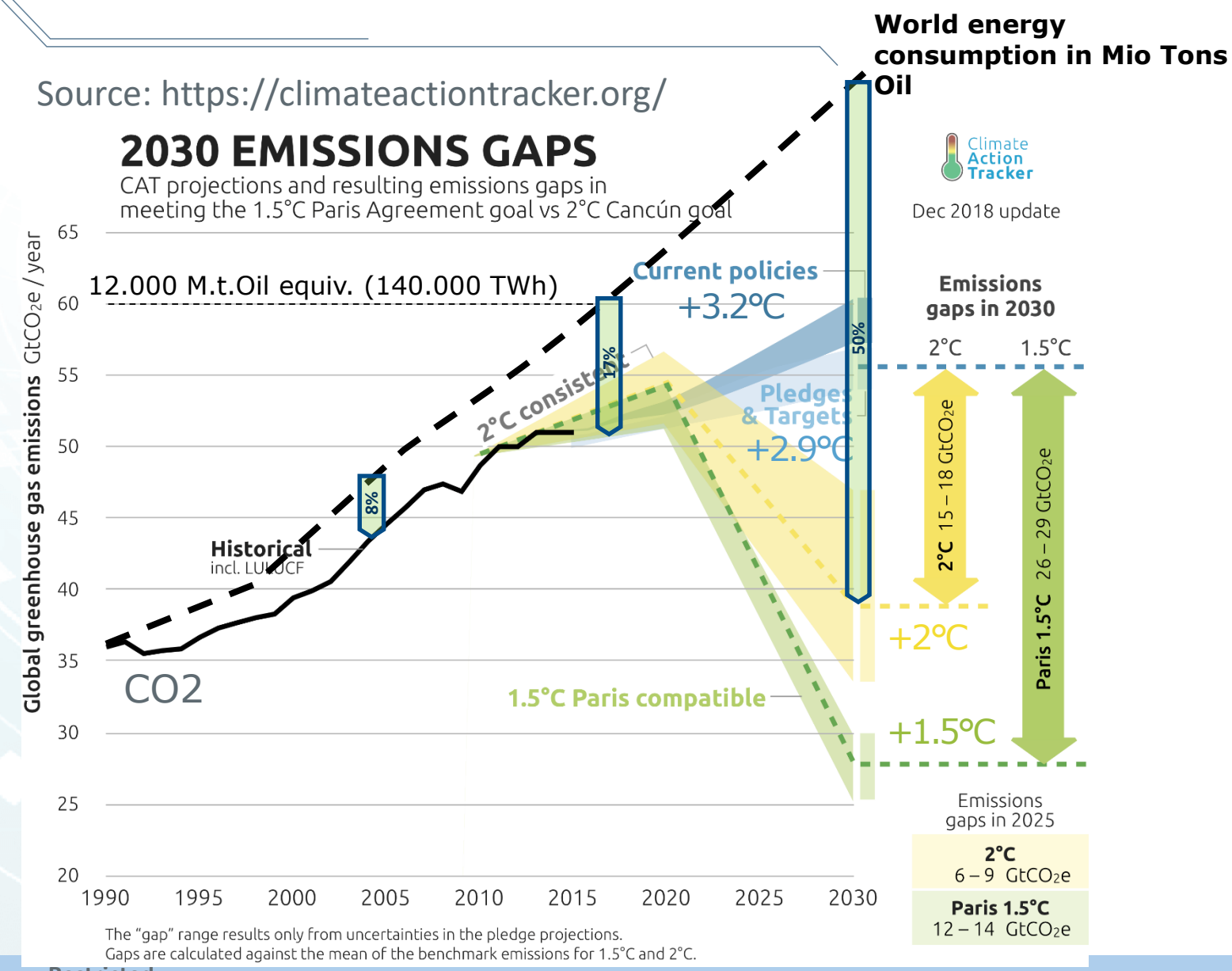
www.obelics.eu

www.obelics.eu

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769506.

GLOBAL WARMING

Source: https://climateactiontracker.org/

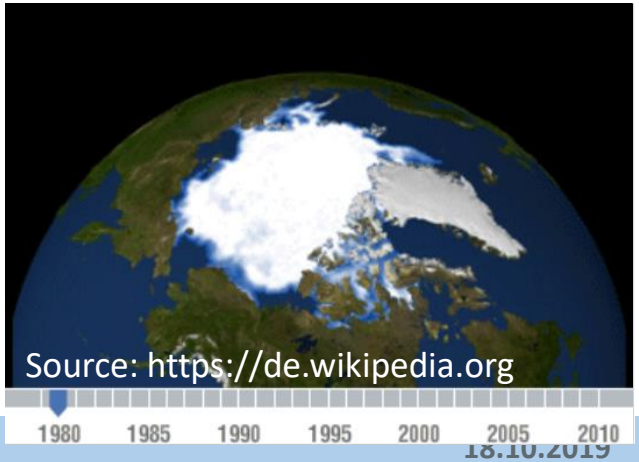


World energy consumption in Mio Tons Oil

Climate Action Tracker

Dec 2018 update

possible consequences

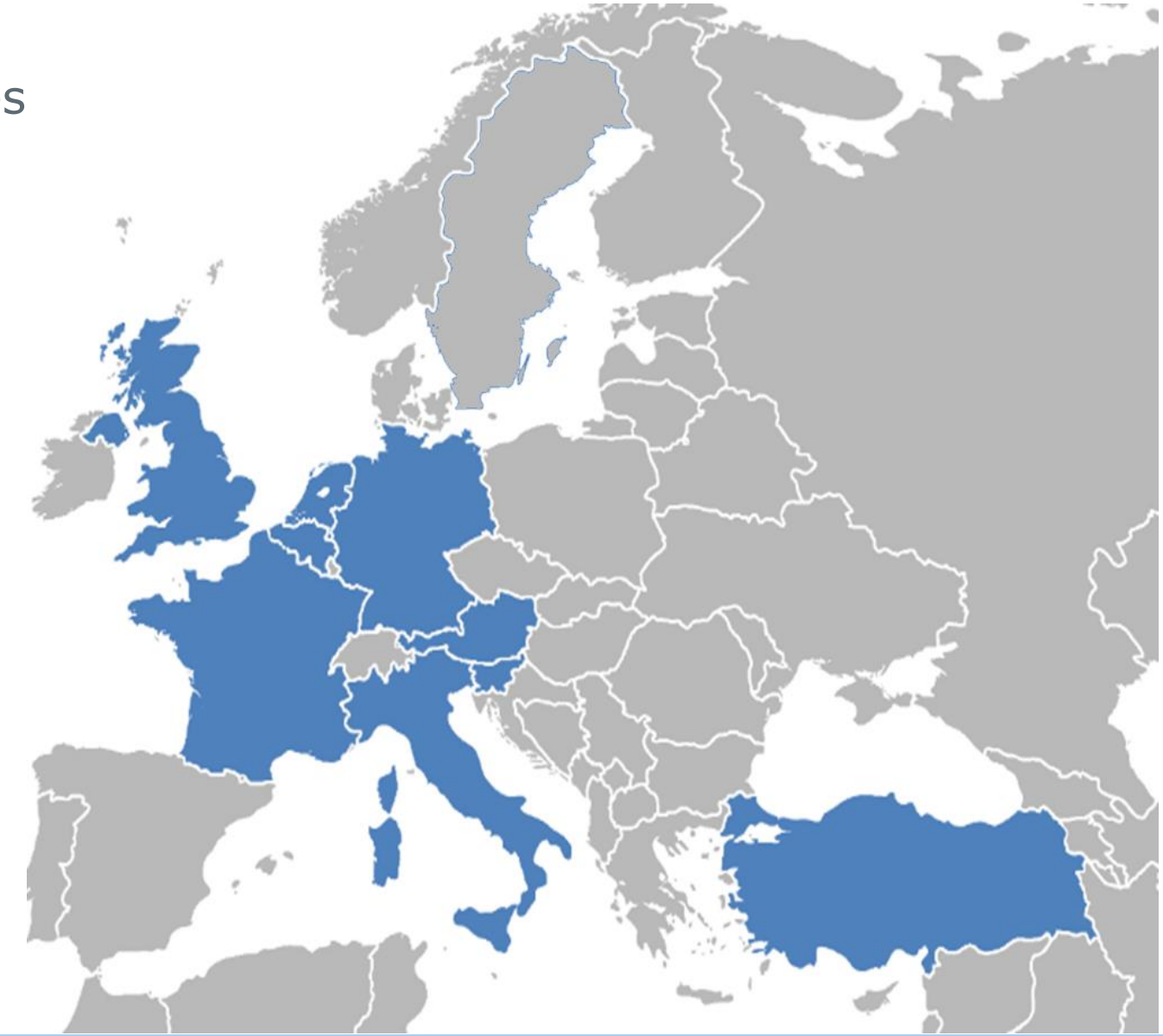


OBELICS VISION

- The overall objective of OBELICS is to develop a systematic and **comprehensive framework**
- for the **design**, **development and testing** of **advanced e-powertrains** and **EVs line-ups**,
- **to reduce development efforts by 40%**
- while **improving efficiency of the e-drivetrain by 20%**
- and **increase safety by a factor of 10** using
- OBELICS advanced heterogeneous **model-based testing methods** and tools,
- as well as **scalable and easy to parameterize real-time models**.
- The baseline for the OBELICS project form results from previous research projects, such as ASTERICS, IMPROVE, ACOSAR, FIVEVB, 3CCAR, etc.

PROJECT KEY FACTS

- 19 Partners from 9 different countries
- Project Budget: 9.077.497,50 EUR
- 994 Person month
- Project Start: 1.10.2017
- Duration: 36 months
- Coordinator: AVL List GmbH



PARTNERS

Coordinator Graz

Regensburg

Belgium

France

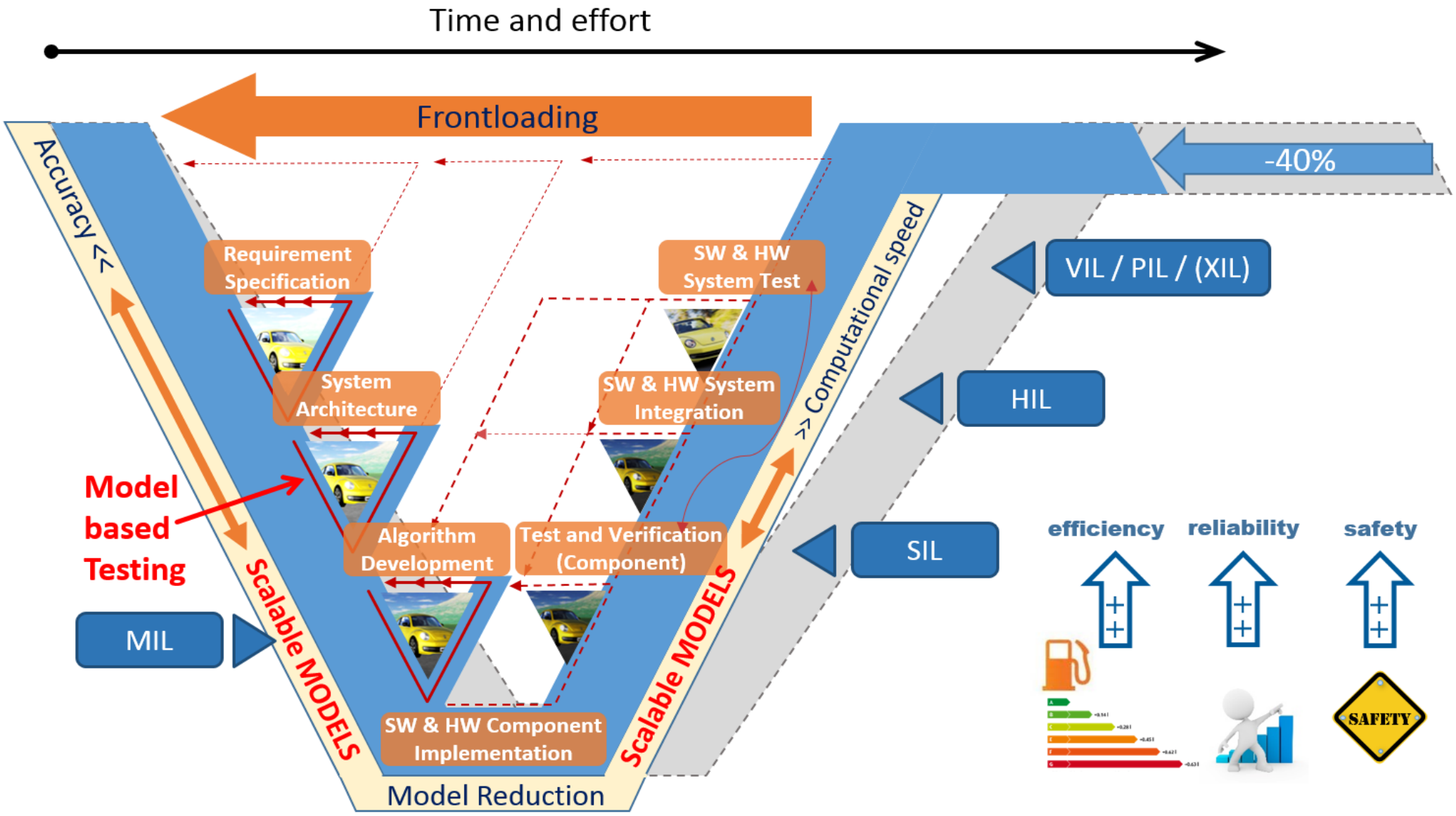
Car manufacturers
- ❑ Renault Trucks SAS - Volvo Group
- ❑ CRF / FCA
- ❑ Ford Otosan

SW, HW, 1st tier suppliers
- ❑ Bosch
- ❑ Valeo
- ❑ AVL, AVL-SFR
- ❑ SIE-NV, SIE-SAS

SME's
- ❑ Uniresearch

Research Organsiation
- ❑ Virtual vehicle, VIF
- ❑ Fraunhofer-LBF
- ❑ FH Joanneum
- ❑ Uni Ljubljana
- ❑ Uni Firence
- ❑ Vrije Univ. Brussels
- ❑ National Inst. Chemistry
- ❑ Uni Surrey

OBELICS APROACH

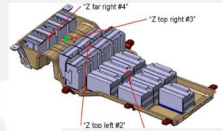


WORK PACKAGE STRUCTURE & USE-CASES

- WP1+5 **Use cases and Safety assessment** methods set the boundaries and requirements for the main work in the project

- WP2 **Scaleable real-time models**
- WP3 System **model integration**
- WP4 **Functional Testing**

- WP6 **Demonstration & Evaluation** & Measure objectives
- WP7 **Standardization, Dissemination, Exploitation**

Engineering categories (Use Case Cluster)
1. New e-drive concept & component sizing in earlier design phase (scalable models) ➔ 3 use-cases
2. E-vehicle system integration, optimization with real world verification (model-based testing) ➔ 5 use-cases
3. Battery design and testing for improved safety & reliability ➔ 4 use-cases 
4. E-motor, control and inverter design & testing ➔ 5 use-cases

BATTERY RELATED ACITVITIES

- Battery testing procedures, EIS
- Battery safety testing & assessment, probFMEA
- Battery testing devices, 20kHz
- Battery modelling, macroscopic models
- Battery model integration/interfaces(comparison with HiFi-Elem), FMI, use for design & optimization
- Battery attribute assessment methodology

TESTING FOR BATTERY PARAMETER IDENTIFICATION

What's new?

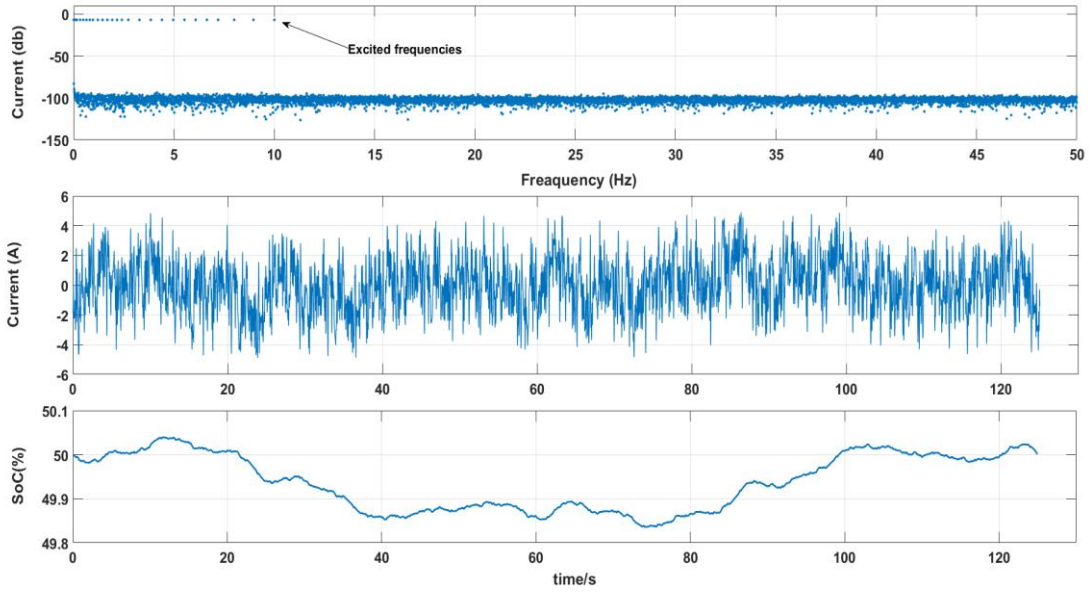
- Advanced **multisine-based** excitation signal in frequency domain
- Scanning **frequency spectrum** of battery at once
- **Fast** and **accurate** battery parameterization in **wide range** of frequency

How does it add value?

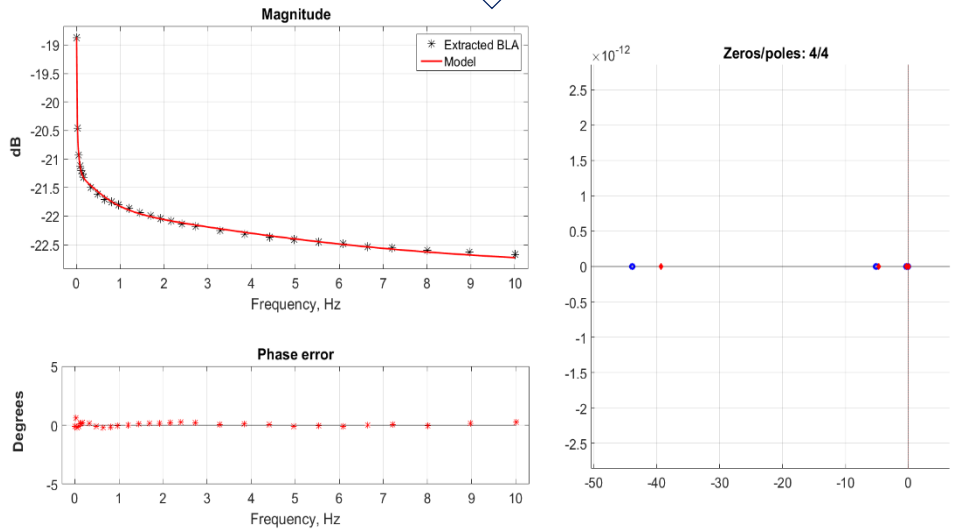
- Increase accuracy at wider range of frequencies
- Reducing parametrization time
- A method for complex systems parametrization

Route to exploitation:

- This method can help battery manufacturers to model and optimize their products.



A dynamic battery input current based on a multisine signal in time and frequency domain



- Accurate parametrization
- Low amplitude/phase error
- Model stability assurance

BATTERY RELATED ACITVITIES

- Battery testing procedures, EIS
- Battery safety testing & assessment, probFMEA
- Battery testing devices, 20kHz
- Battery modelling, macroscopic models
- Battery model integration/interfaces(comparison with HiFi-Elem), FMI, use for design & optimization
- Battery attribute assessment methodology

SAFETY AND RELIABLITY ASSESSMENT METHODS

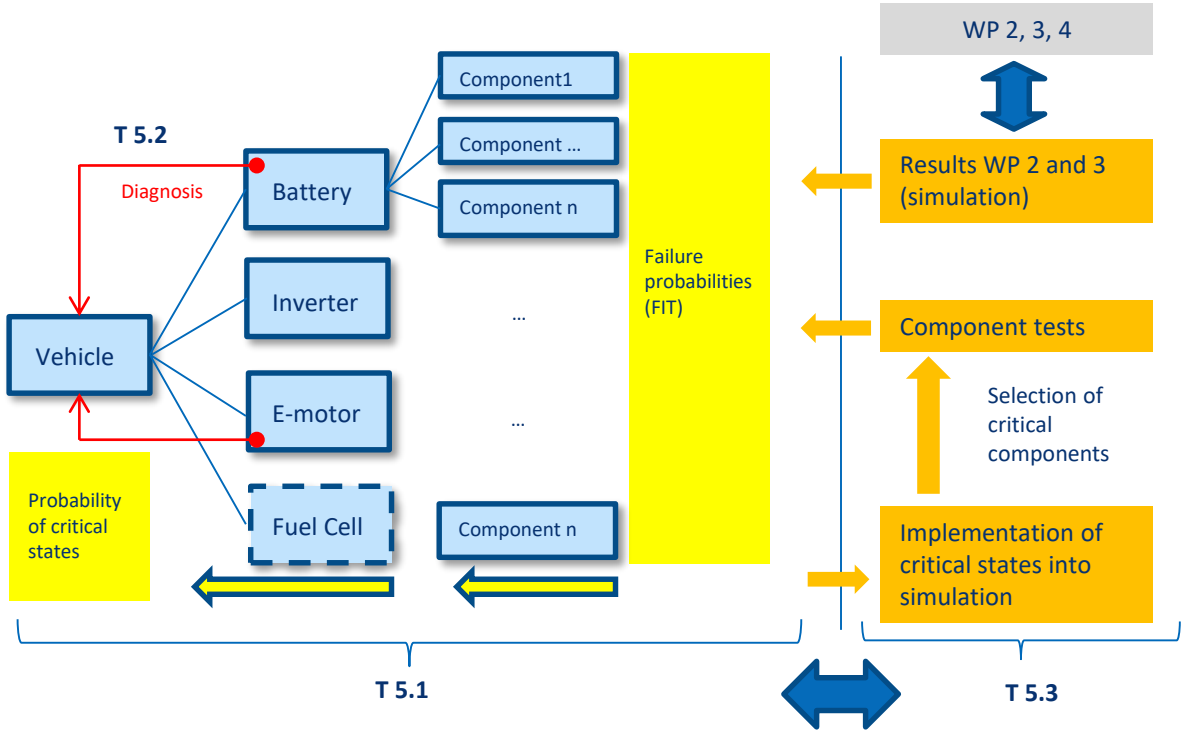
Objective

- ❑ Increase safety of battery system by a **factor of 10**
- ❑ Reduce development and testing **efforts** for battery systems by **40%.**

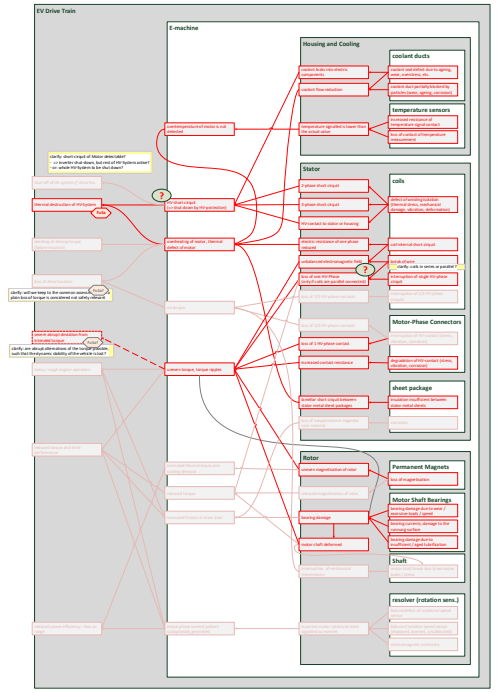
Whats new

- ❑ Improvement of **safety** by taking the electrical and the mechanical reliability into account
- ❑ Reliability assessment with probablistic FMEA, *prob*FMEA ECU
- ❑ Real world battery testing technologies

Story line of WP5



prob-FMEA



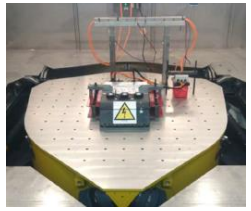
SAFETY AND RELIABLITY ASSESSMENT METHODS

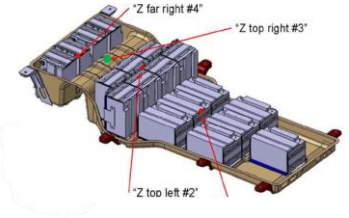
Comparison of internally measured spectrum (orange) with ISO 12405 (blue) on sensor 4

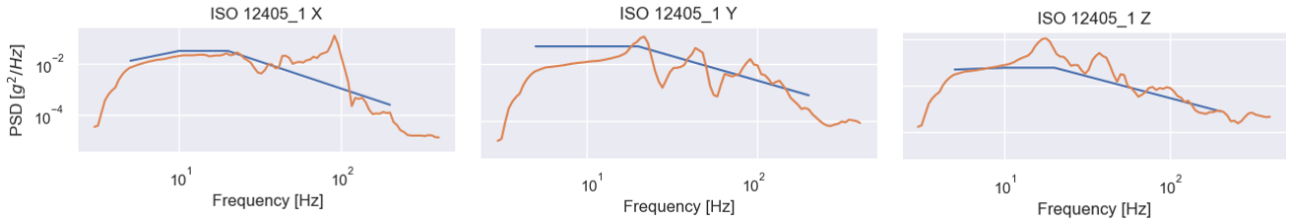
The comparison of internal and external accelerations shows that

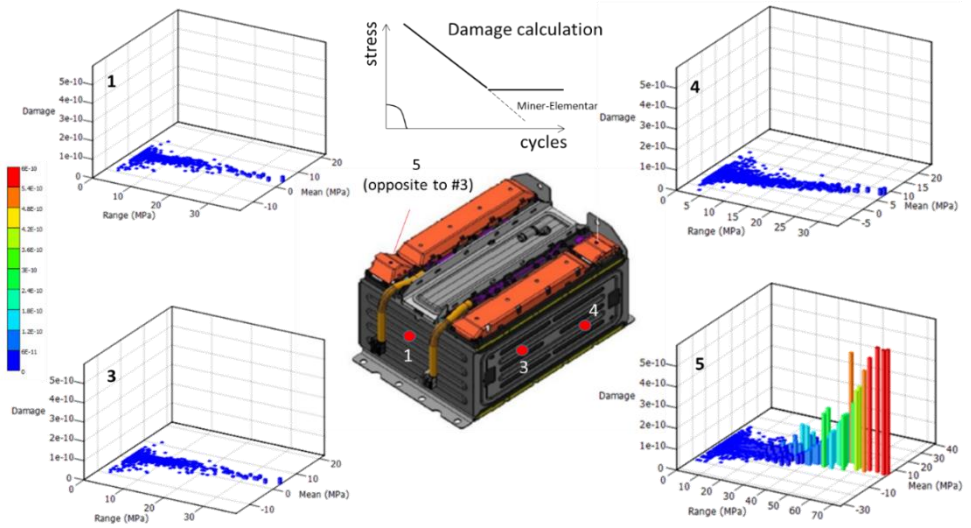
- the internal accelerations are higher than the external, and
- the internal accelerations exceeds the ISO 12405 spectrum in every direction in the frequency .

Battery module incl. the positions of the strain gauges and the result of the damage accumulation of each position for the used drive cycle at 100% SOC









BATTERY RELATED ACITVITIES

- Battery testing procedures, EIS
- Battery safety testing & assessment, probFMEA
- Battery testing devices, 20kHz
- Battery modelling, macroscopic models
- Battery model integration/interfaces(comparison with HiFi-Elem), FMI, use for design & optimization
- Battery attribute assessment methodology

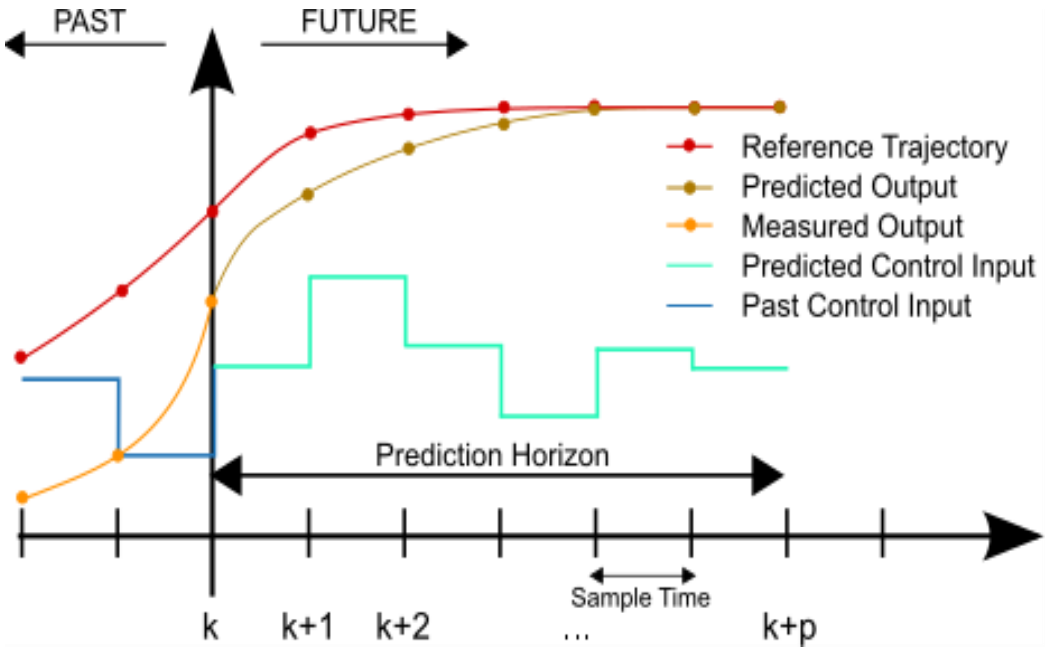
BATTERY TESTING DEVICES

Novel controller algorithms on fast FPGA-based platforms to enable real-world behavior and dynamics of P-HIL devices for emulation of electric vehicle components

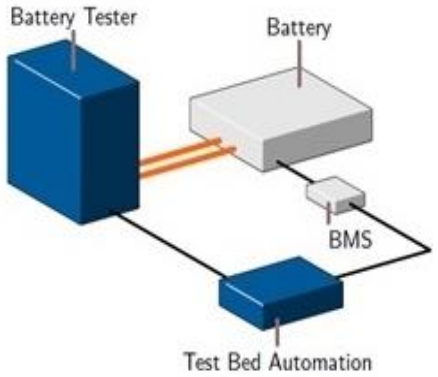
Illustration of Model Predictive Control technique

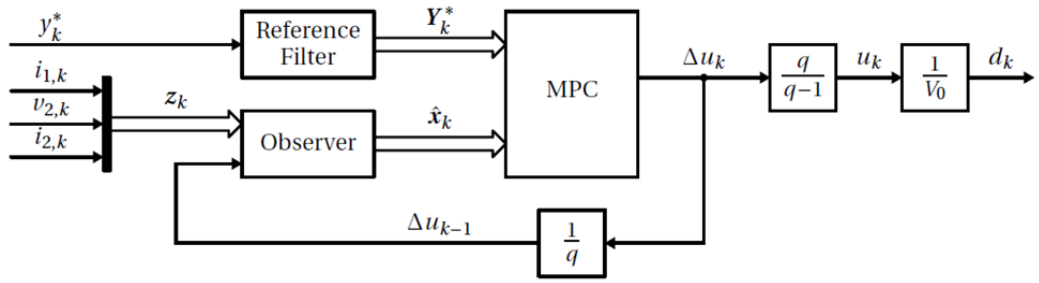
The idea can be summarized as below:

- Use a **mathematical model** of plant & present **measurements** to predict future output
- Calculate control sequence which minimizes the **cost function**
- Apply the first control signal of the calculated sequence
- Repeat steps from 1 to 3 for the next sampling time



MPC controller architecture





BATTERY RELATED ACITVITIES

- Battery testing procedures, EIS
- Battery safety testing & assessment, probFMEA
- Battery testing devices, 20kHz
- Battery modelling, macroscopic models
- Battery model integration/interfaces(comparison with HiFi-Elem), FMI, use for design & optimization
- Battery attribute assessment methodology

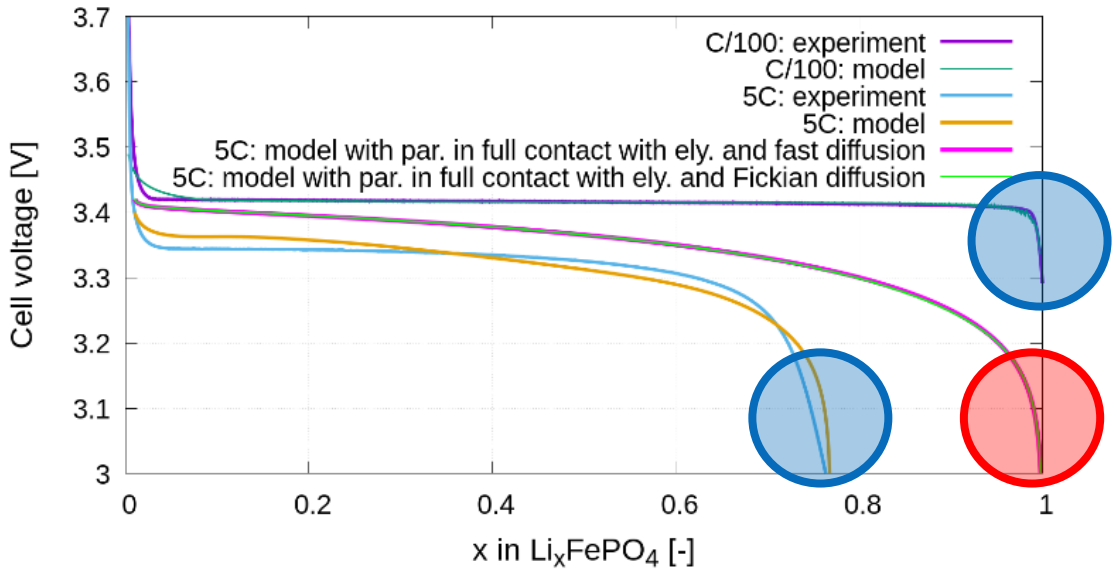
MODELLING – ADVANCED ELECTROCHEMICAL BATTERY MODEL

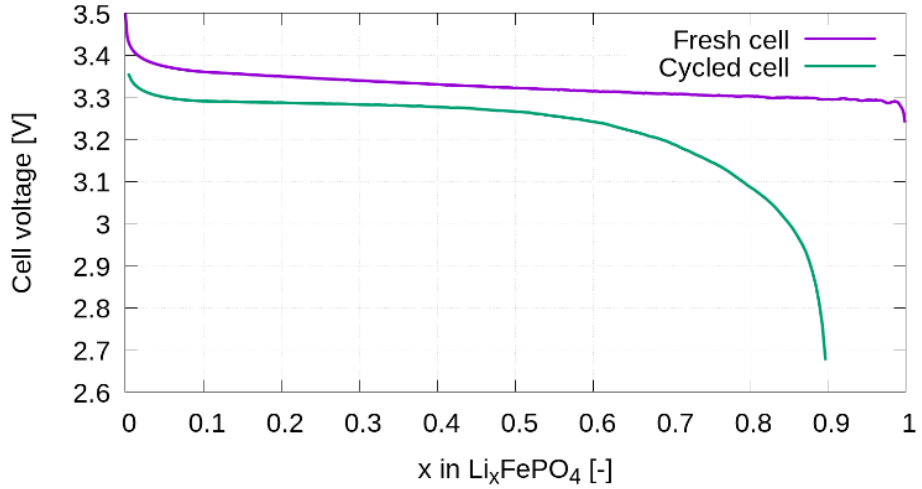
Objective:

- Developing detailed innovative modelling approaches that allow for systematic scalability towards realtime models

What is new?

- More consistent virtual representation of electrodes and underlying processes
- Higher prediction capability and accuracy of the model for new and aged cells
- Full coupling with degradation models
- Safety analyses: Modelling onset of thermal runaway

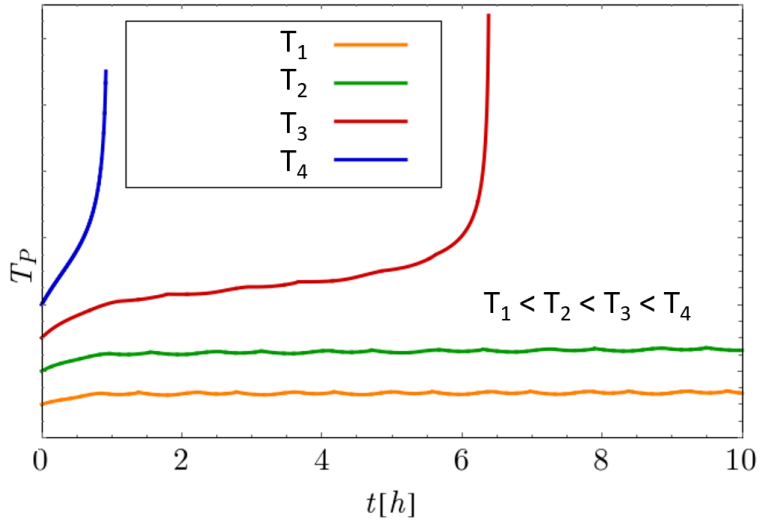




Modelling capacity fade and voltage drop due to SEI growth

Consistent representation of electrodes: Good agreement between experimental and modelled LFP half-cell potentials during discharge for high and low C-rates

Inconsistent (Newman based) representation of electrodes: inconsistent prediction of Li-utilization due to small particle sizes and missing connectivity

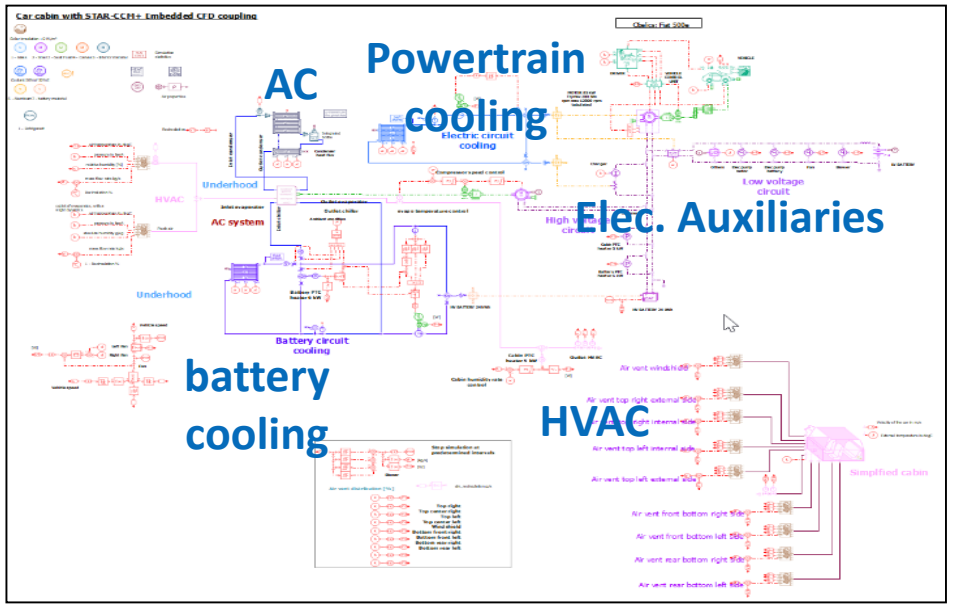


Modelling onset of thermal runaway

BATTERY RELATED ACITVITIES

- Battery testing procedures, EIS
- Battery safety testing & assessment, probFMEA
- Battery testing devices, 20kHz
- Battery modelling, macroscopic models
- Battery model integration/interfaces(comparison with HiFi-Elem), FMI, use for design & optimization
- Battery attribute assessment methodology

SYSTEM MODEL INTEGRATION & OPTIMIZATION



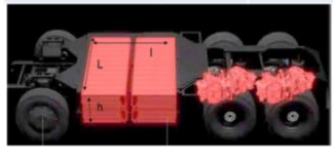
Objective:

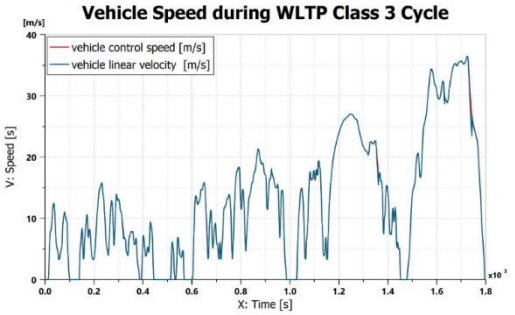
- ❑ - Reduction of development & testing efforts with virtual simulation & frontloading

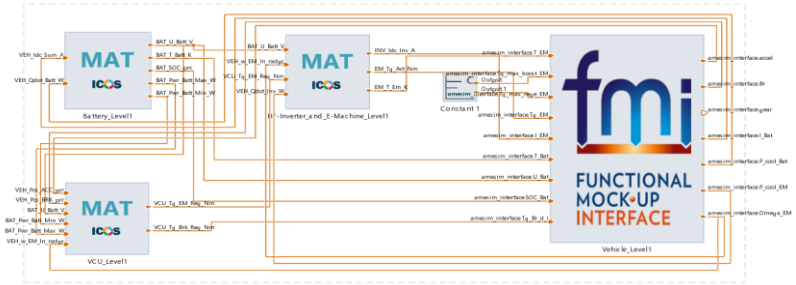
What is new?

- ❑ EV physical model integration with high-accuracy
- ❑ Thermal system integration models
- ❑ Control strategies & automated calibrations with real driving conditions
- ❑ Complexity reduction of components models for real-time integration and analysis
- ❑ EV optimization and trade-off
- ❑ Simulation toolchains, FMI/FMU model integration
- ❑ Co-simulation and signal delay-compensation

Powertrain characteristics	
Number of EM	4
EM Peak power (kW)	192
Fixed reduction Gear (rear axle 1)	-
Fixed Reduction Gear (rear axle 2)	-







MODEL INTERFACES, INTERACTIONS WITH HIFI-ELEMENTS

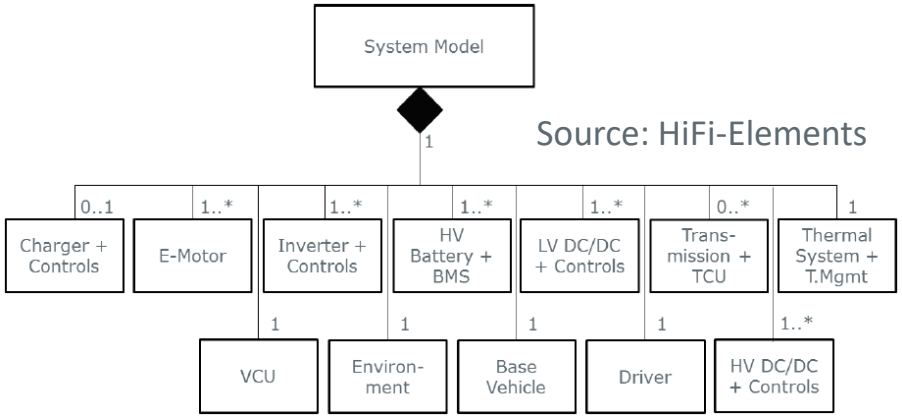
HIFI-ELEMENTS
High Fidelity Electric Modelling and Testing

obelics

- **Objective:**
  > Harmonization of the modelling approaches and signal standards

- **Meetings:**
  > Already 2 F2F-meetings and 3 WebEx-meetings
  > Common dissemination event planned

- **Results until yet:**
  > Exchange of modelling approaches
  > Exchange of interface definitions
  > Exchange of Subsystem Identy Card
  > OBELICS partners will further assess the HiFi-Elements interface definitions in several use-cases
  > HiFi-Elements partners will assess/use the SIC



OBELICS: **SIC** Subsystem Identiy Card

Subsystem Identity Card							
Subsystem model specific information							
Name of subsystem	e.g. LilonBattery						
From Partner	ViF, AVL, FO, US, ...						
Use Case Cluster	1, 2, 3						
Use Case Number	2.1, 2.3, ...						
Short description	purpose, usage, additional information, subsystem dynamics ...						
Known limitations	for specific simulations only - valid in specific operating conditions, ...						
...	individually list extentions						
Inputs of the subsystem							
Name / Description	Unit	Lower Limit	Upper Limit	Data Type	Dimension	Init Value	
Outputs of the subsystem (at least the relevant ones)							
Name / Description	Unit	Lower Limit	Upper Limit	Data Type	Dimension		
Simulation specific information							
Simulation tool & version	Matlab/Simulink 2010a, MSC-Adams 2010, ...						
Numerical solver	Ode45, Dassl, Euler, ...						
Kind of numerical step-sizes	fixed, variable, both, ...						
Numerical step-size	fixed step-size - max step-size in case of variabel step-size solver						
Real-time capable	yes/no						
Project licence available	yes/no						
...	individually list extentions						
Hardware specific information							
Hardware description	dSPACE MikroAutoBox, Testbed, HiL, ECU, ...						
Communication step-size	fixed step-size						
Communication medium	UDP, CAN, ...						
...	individually list extentions						

Name
VTMld_T_CooltMaxAvlBatt_K
VTMld_T_CooltMinAvlBatt_K
VTMld_Vt_CooltMaxAvlBatt_m3ps
VTMld_Vt_CooltMinAvlBatt_m3ps
BVld_T_AmbAir_K
BVld_Hum_AmbAir_perc
VTMpd_T_CooltInlBatt_K
VTMpd_Vt_CooltFlowBatt_m3ps
CHpd_I_ChrgnBatt_A
VTMpd_P_CooltInlBatt_Pa

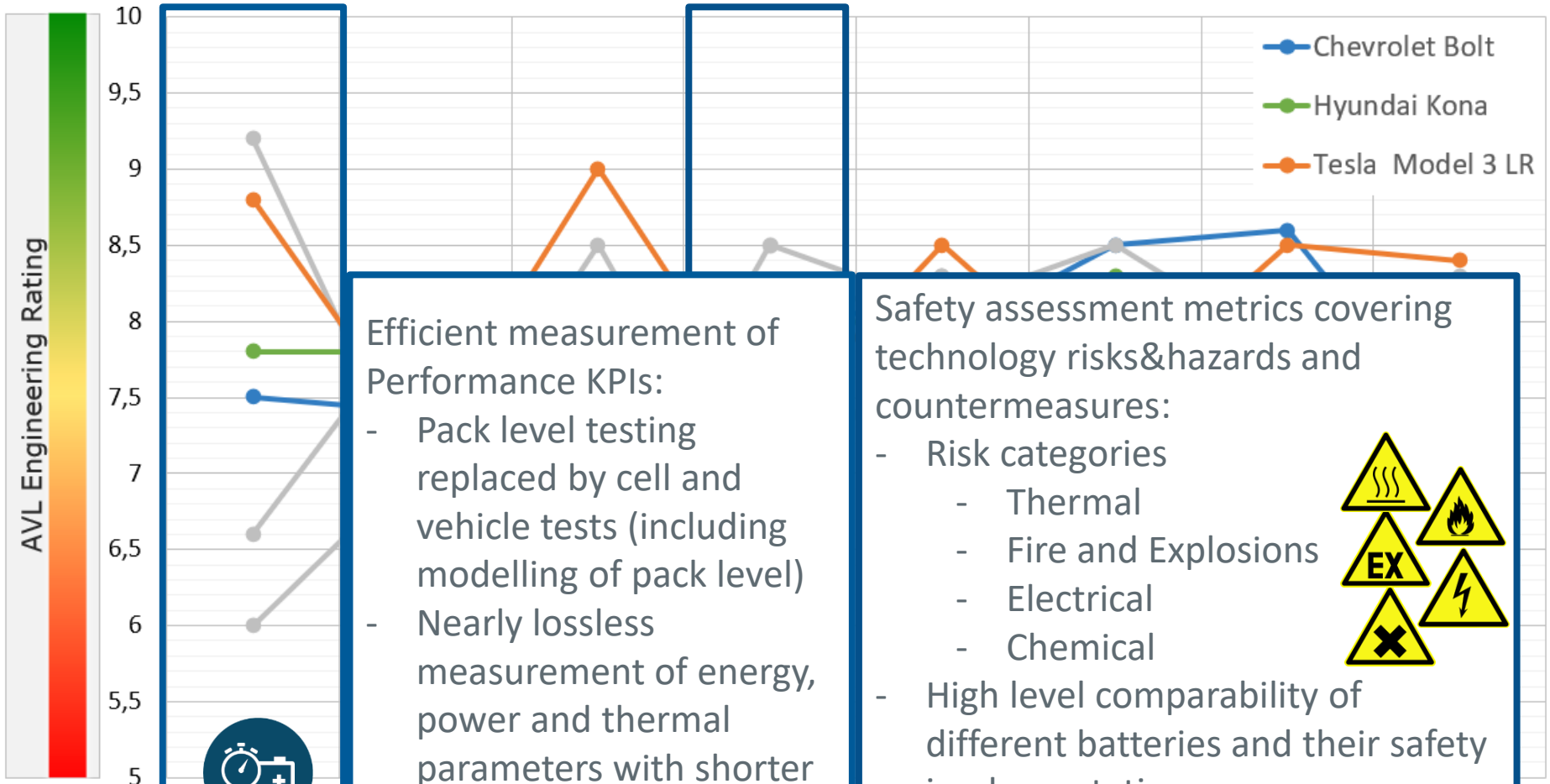
Variables
Battery current
Battery maximum power
Battery minimum power
Battery coolant temperature
Battery voltage
Battery state of charge
Battery state of health
Battery power losses
Battery heat rejection to coolant
Battery temperature

BATTERY RELATED ACITVITIES

- Battery testing procedures, EIS
- Battery safety testing & assessment, probFMEA
- Battery testing devices, 20kHz
- Battery modelling, macroscopic models
- Battery model integration/interfaces(comparison with HiFi-Elem), FMI, use for design & optimization
- Battery attribute assessment methodology

BATTERY ATTRIBUTE ASSESSMENT

9 - 10	excellent
8 - 9	good
7 - 8	satisfying
6 - 7	acceptable
5 - 6	poor
4 - 5	unacceptable
3 - 4	defective
2 - 3	unsafe operation
1 - 2	no operation



Efficient measurement of Performance KPIs:

- Pack level testing replaced by cell and vehicle tests (including modelling of pack level)
- Nearly lossless measurement of energy, power and thermal parameters with shorter and more cost efficient test program
- Partners: VUB, CEA, AVL-ITS

Safety assessment metrics covering technology risks&hazards and countermeasures:

- Risk categories
  - Thermal
  - Fire and Explosions
  - Electrical
  - Chemical
- High level comparability of different batteries and their safety implementation
- Partners: Fraunhofer-LBF, CEA, University Ljubljana

CONTACT INFORMATION

OBELICS Project Coordination

- Project Coordinator
  Horst Pfluegl
  AVL List GmbH
  Horst.Pfluegl@avl.com

- Project Manager
  Anish Patil
  Uniresearch
  A.Patil@uniresearch.com

- Project home page www.obelics.eu

Optimization of scala**B**le r**E**altime mode**L**s and funct**I**onal testing for e-drive **C**oncept**S**

This project has received funding from the European Union's Horizon 2020 research and innovation programme *under grant agreement No 769506.*