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

COLLABAT Webinar – Testing subcluster
Against all odds: cell testing activities in MARBEL and modelling approaches

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DATE: 29.11.2023

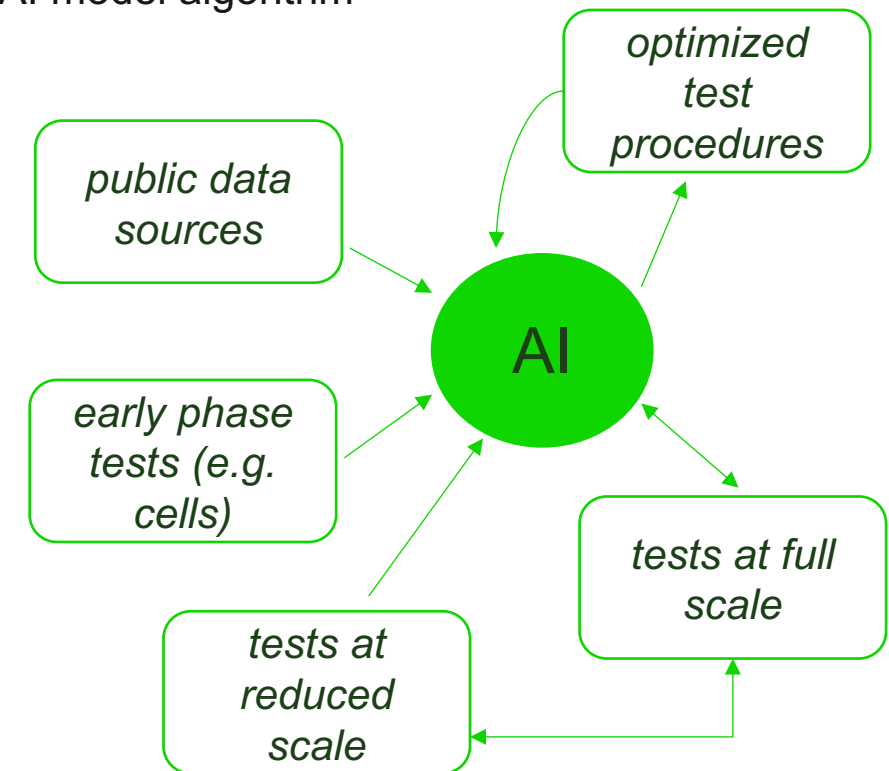# *Against all odds??*

struggle #1: getting the cells!

- decision on cells to be used done
- → test cells ordered in after negotiations in summer 2021
- → manufacturer mentions October as delivery date
- → silence…..
- → October passes by….
- → asking for updates….
- → silence…
- → manufacturer says October can't be kept anymore.. surprise!
- → new date: end of November 2021
- → accepted…
- → manufacturer wants test plan with every info about planned tests
- → test plan delivered to manufacturer…

- money transferred to manufacturer
- end of November 2021: money received, but cells can't be delivered, since no customer account created (?!)
- mid December 2021: update??
- can't ship, since no GTCs defined
- beginning January 2022: we ask for an update
- silence….

…to be continued…

- Overall target: Validate and benchmark MARBEL BP system's performance and safety

- Derive innovative test procedures to reduce time and cost effort in future testing

- Combine system knowledge from other WPs and test results as a base for an AI model algorithm

- Use the AI-model output to
  - reflect the test procedures and improve them
  - validate the scalability of test results

- This will be achieved by following concepts:
  - start testing from early development stages
  - interact with other WPs to build a strong AI knowledge base
  - include publicly available data for AI training
  - mechanical tests with a miniaturized housing of the novel BP
  - validate the system behaviour at full scale in a novel test environment
    eVIL "electric-vehicle-in-the-loop"

public data sources

optimized test procedures

AI

early phase tests (e.g. cells)

tests at full scale

tests at reduced scale

Objective: improve knowledge gain with test data and improve efficiency in future test-procedures

List and categorize common test procedures

Determine:
- Intention of test / expected result
- Time effort
- Tools/equipment needed
- Previous/Subsequent Test
- State of DUT before+after test
- Staff needed

Goal:
„Cost"-Factor
„Efficiency"

AI

new test procedures

Selection of (existing) tests

Build test scenarios

Derive model parameters

COLLABAT „collection file"

mini BP-housing tests

data-driven cell model

EC cell model

Desired results, e.g.:
- R_i vs. T/SoC/I
- Cycle Life
- Peak Power
- …

model

- extensive characterization necessary?
- what parameters can be deduced?
- can results be scaled to a larger scale?

Against all odds??

…what about the cells though..??

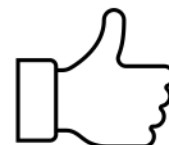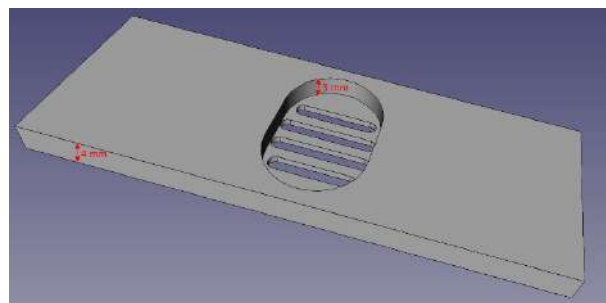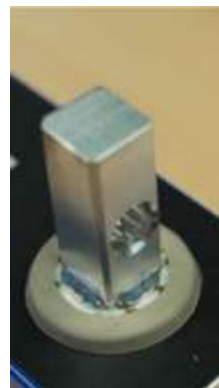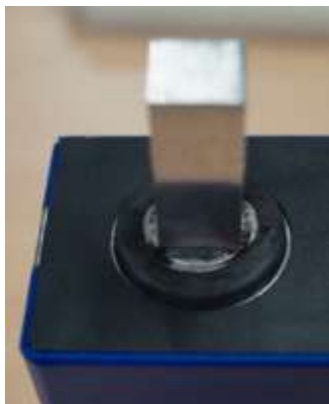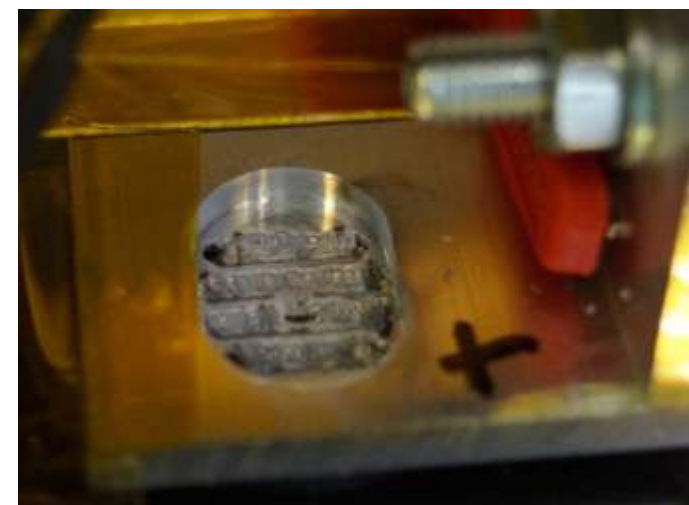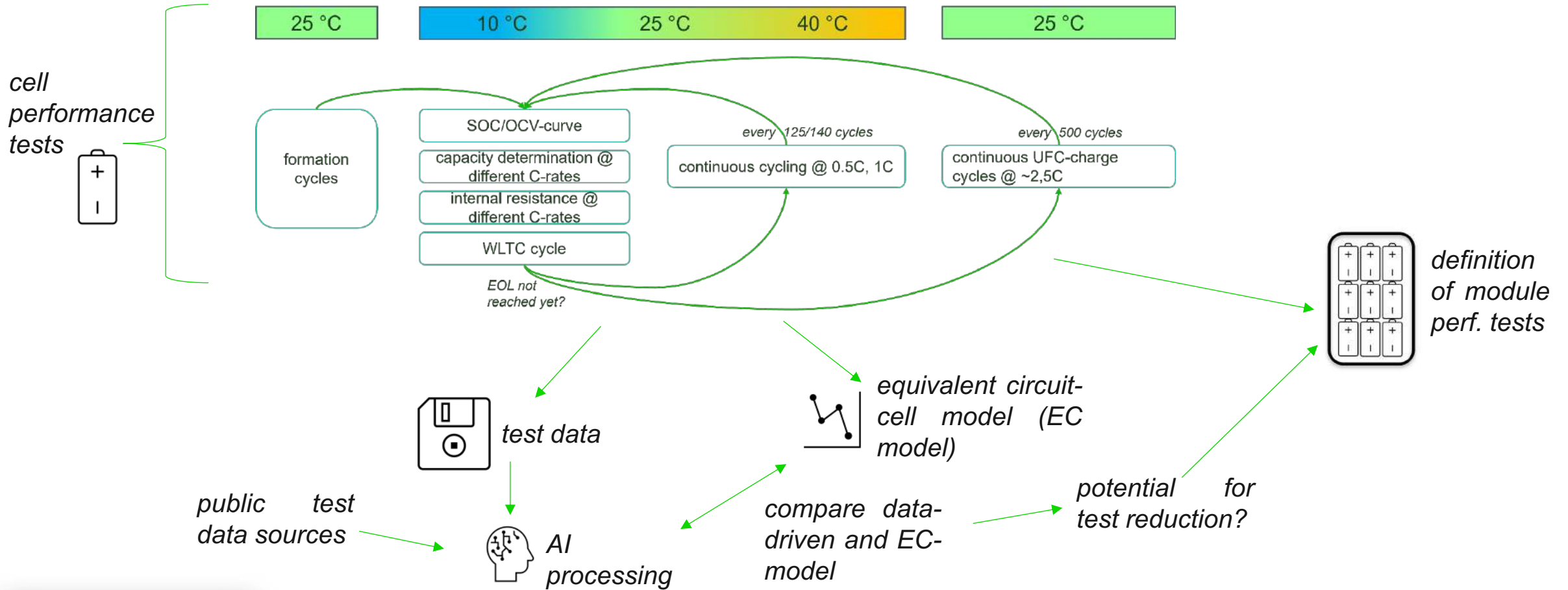**→ end January 2022: test cells arrive!!**

source: giphy.com

struggle #2: contacting the cells + starting test with literally 0 information!

currently in use for testing:
laser-welded aluminum tabs

cell performance tests

| 25 °C | 10 °C   25 °C   40 °C | 25 °C |

formation cycles

SOC/OCV-curve

capacity determination @ different C-rates

internal resistance @ different C-rates

WLTC cycle

EOL not reached yet?

every 125/140 cycles

continuous cycling @ 0.5C, 1C

every 500 cycles

continuous UFC-charge cycles @ ~2,5C

test data

equivalent circuit-cell model (EC model)

definition of module perf. tests

public test data sources

AI processing

compare data-driven and EC-model

potential for test reduction?

… in the meantime… ordering (or trying to) the big batch of cells for manufacturing modules + packs…

sounds easy? → :D → wait a second for…

struggle #3 or "the real struggle":
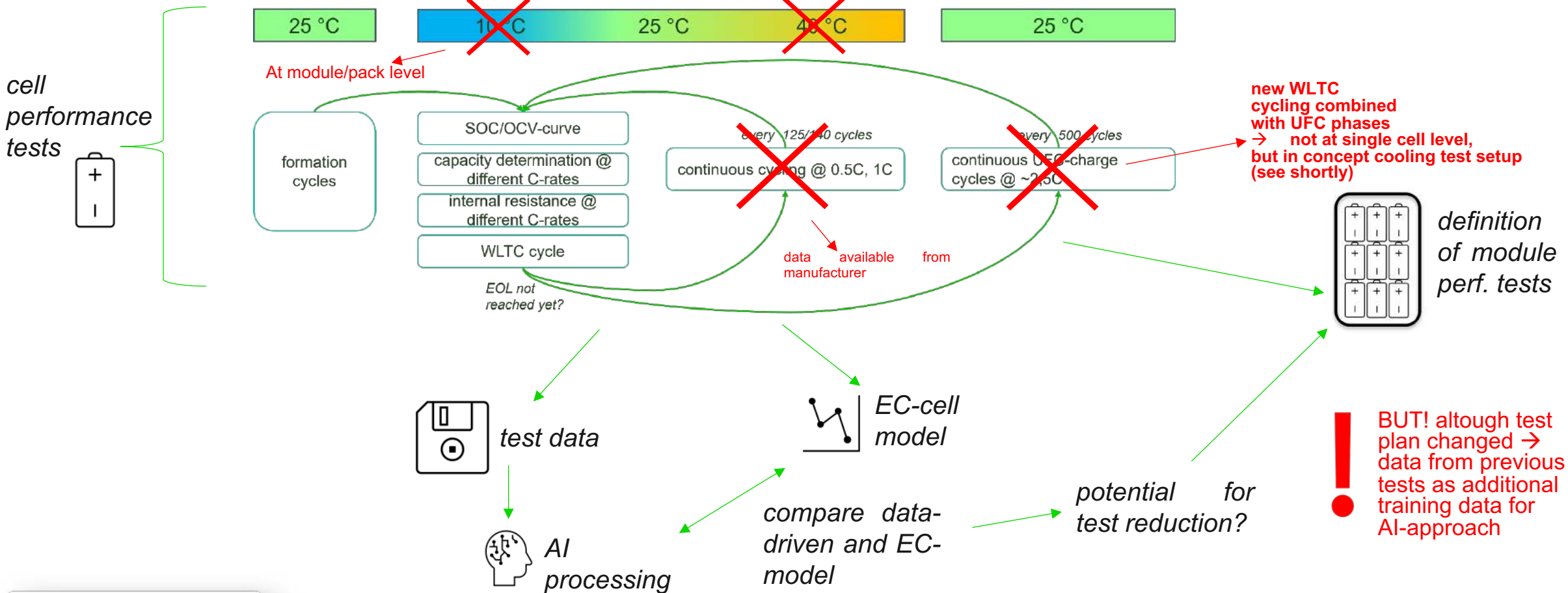   **no more cells from the manufacturer!**

source: giphy.com

need for changing the test strategy and adapting to new cells..

→ adapting cell test plan to new cells (time delay etc.)

At module/pack level

25 °C   10 °C   25 °C   45 °C   25 °C

At module/pack level

cell performance tests

formation cycles

SOC/OCV-curve

capacity determination @ different C-rates

internal resistance @ different C-rates

WLTC cycle

EOL not reached yet?

every 125/140 cycles

continuous cycling @ 0.5C, 1C

data available from manufacturer

every 500 cycles

continuous UFC-charge cycles @ ~2.5C

new WLTC cycling combined with UFC phases → not at single cell level, but in concept cooling test setup (see shortly)

definition of module perf. tests

test data

AI processing

EC-cell model

compare data-driven and EC-model

potential for test reduction?

! **BUT! altough test plan changed → data from previous tests as additional training data for AI-approach**

Concept Cooling Test Setup (2p configuration, "module-like" setup)
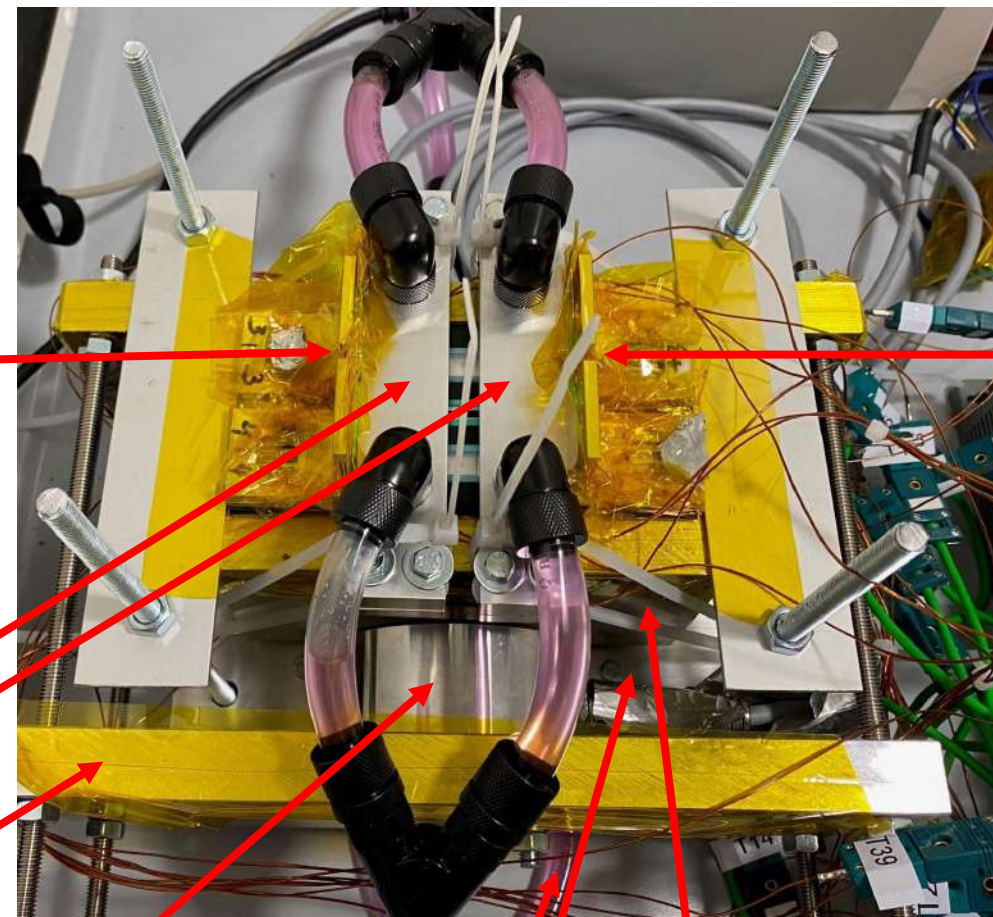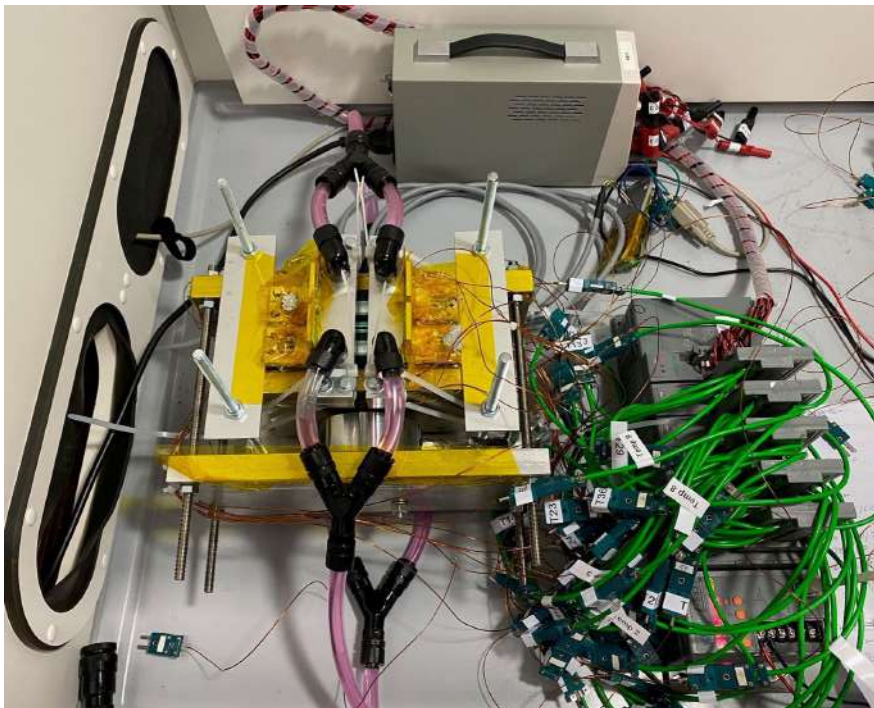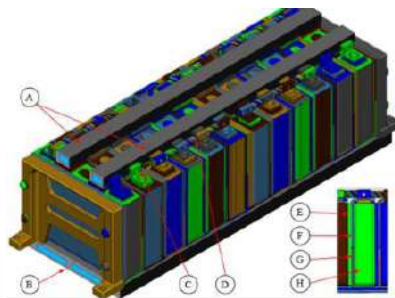

cells neg. terminal

cells pos. terminal

top cooling rails

pretensioning plate
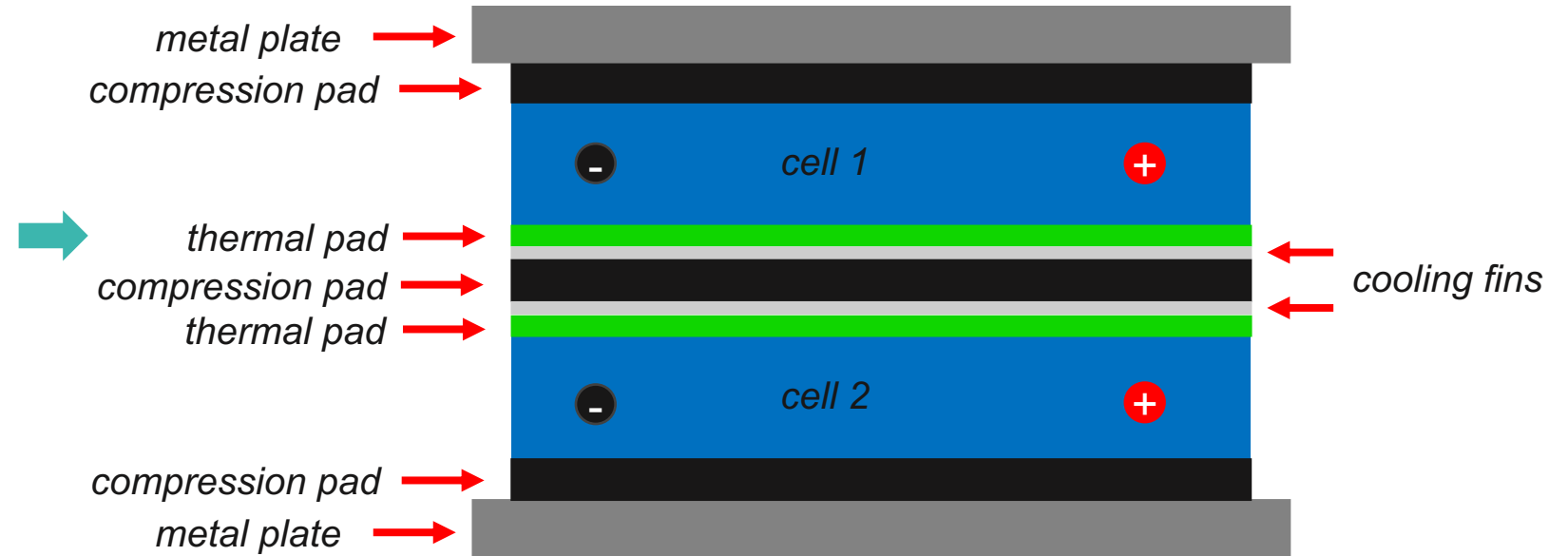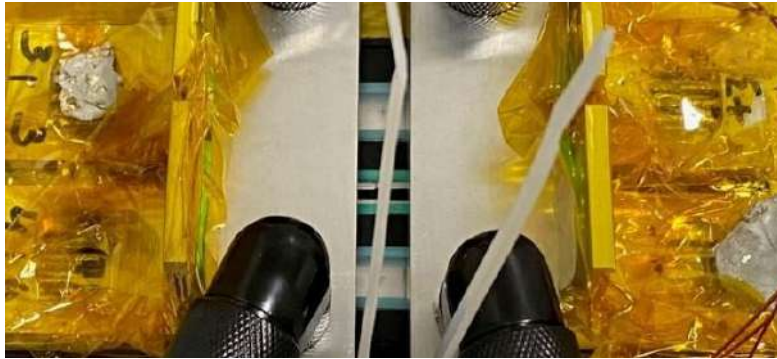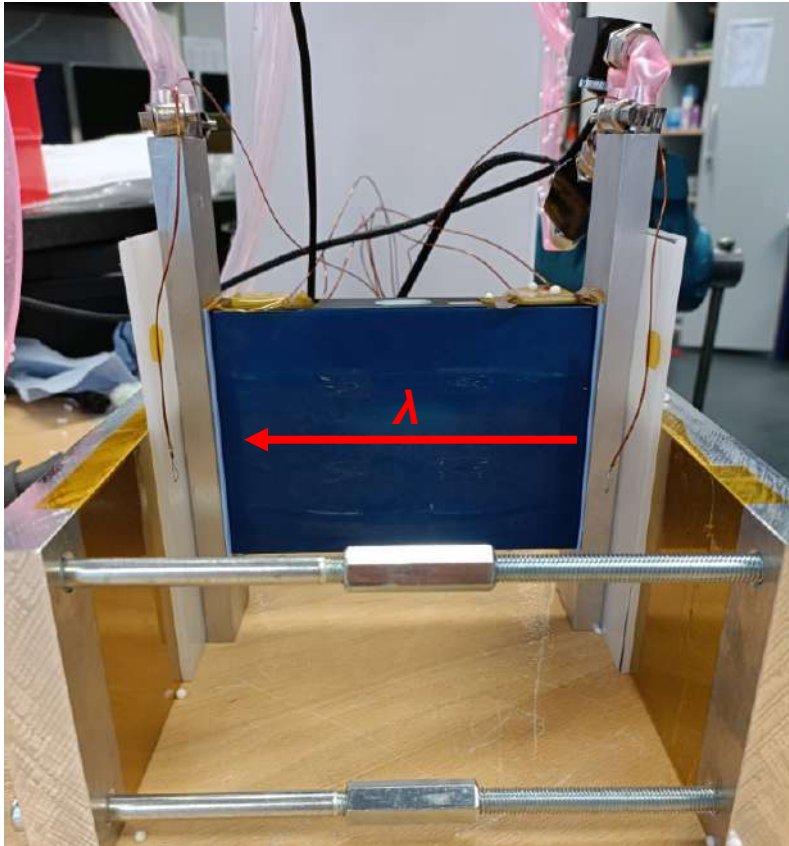
force sensor

bottom cooling
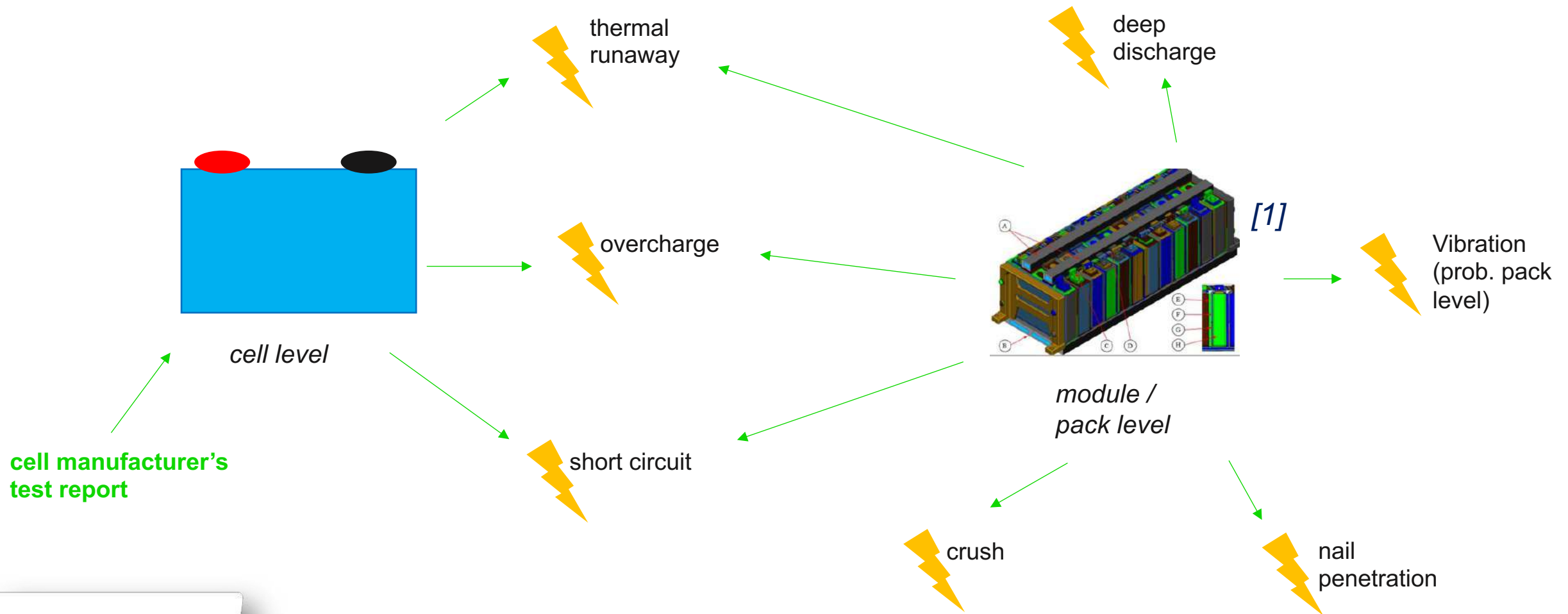
floating plate

[1]

MARBEL

Scopes of this investigation:
- validate and adapt thermal model (detect hotspots, sensor placement?, …)
- investigate swelling behavior of cells in a module-like compound
- keep the cells cycling and investigate degradation

thermal properties of the cells:
- *therm. conductivity in x, y and z-direction*
- *therm. capacity*
- *input for thermal model*
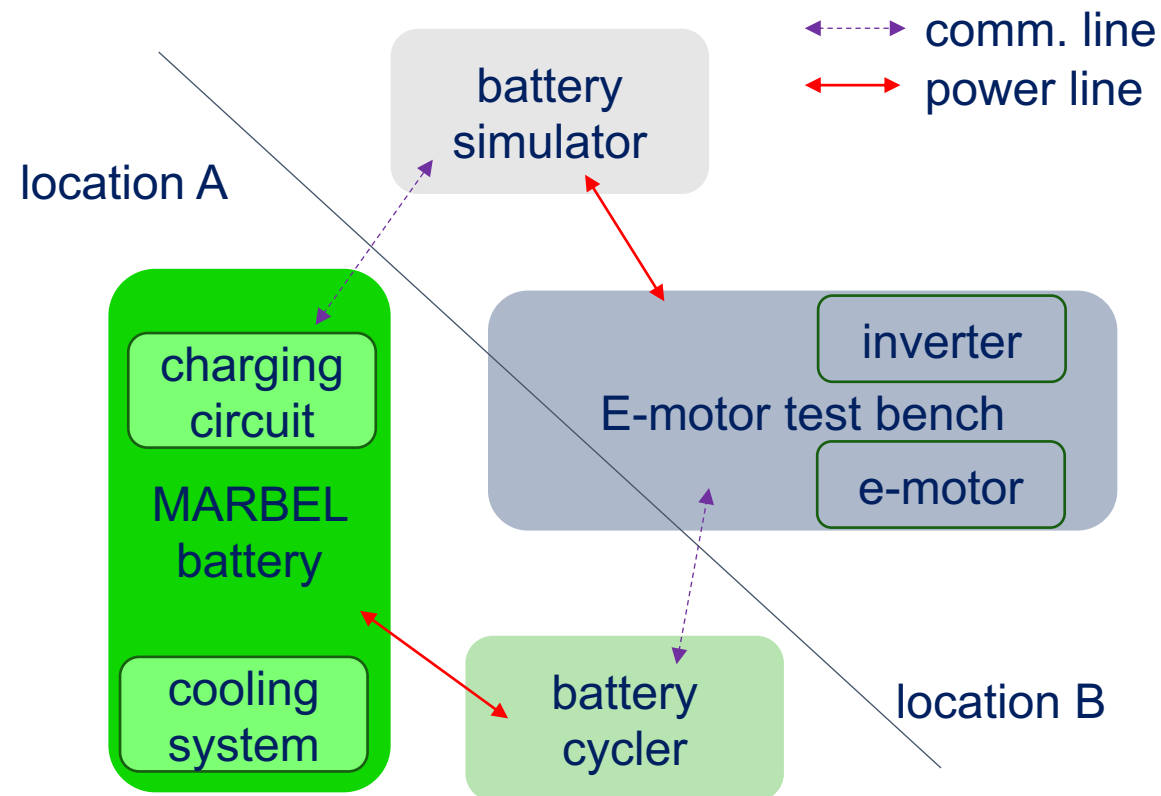- *validation of assumptions used for modelling*

thermal runaway

deep discharge

overcharge

[1]

Vibration (prob. pack level)

cell level

module / pack level
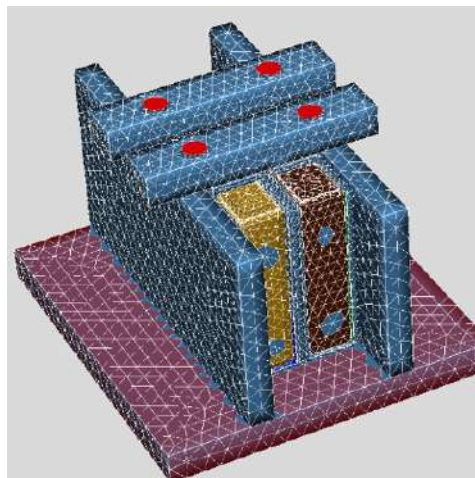
cell manufacturer's test report

short circuit

crush

nail penetration

eVIL test-bench:

- test performance at full scale

- no need of integrating battery in a certain vehicle

- no constraints in terms of dimension / power demands

- complete freedom in package design

- high level of modularity

- battery and motor test bench not necessarily at same location

comm. line
power line

location A

battery simulator

charging circuit

MARBEL battery

cooling system

E-motor test bench

inverter

e-motor

battery cycler

location B

modeling activities

Main input from testing:
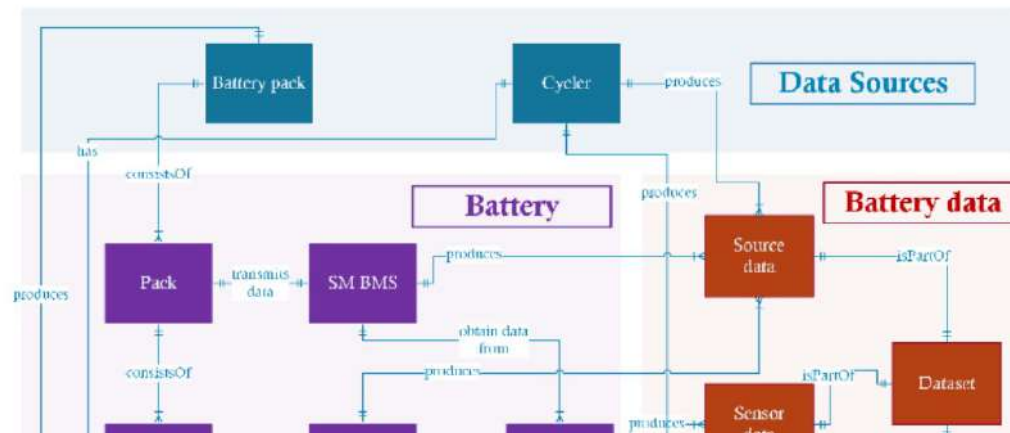**Thermal characterization measurements + concept cooling tests**

thermal model, picture from [1]

Main input from testing:
characterization tests, pulse-profile tests
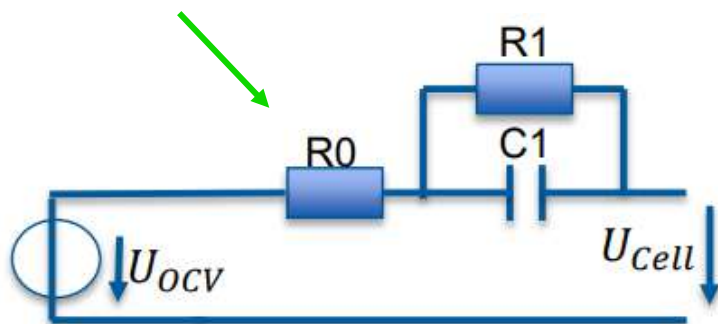
equivalent circuit model

Interfaces? Combinations?

Main input from testing:
continuous cycling data

data driven model, picture from [2]

References

- [1] J. G. Corominas, A. B. Escoda, D. Koch, R. Albrecht, H.-G. Schweiger, "Virtual development of a thermal management system of a high performance battery for electric vehicles," in Proceedings of the FISITA 2023 World Congress, Barcelona, 12 – 15 September 2023.

- [2] Afroditi Fouka, Alexandros Bousdekis, Katerina Lepenioti, Gregoris Mentzas, „Modelling Data-Driven Digital Twins of EV Batteries for Predictive Analytics", in Proceedings of the 14th International Conference on Information, Intelligence, Systems and Applications (IISA2023), Volos, Greece, Juli 2023. doi: 10.5281/zenodo.8181384.

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THANK YOU!

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A project coordinated by:

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